Vol. XX. MAY, 1895. No. 5.

THE BOTANICAL GAZETTE

EDITORS:

JOHN M. COULTER, Lake Forest University, Lake Forest, Ill.
CHARLES R. BARNES, University of Wisconsin, Madison, Wis.
J. C. ARTHUR, Purdue University, Lafayette, Ind.

CONTENTS:

The development of botany in Germany during the nineteenth century. *E. Strasburger*, trans. by *G. J. Peirce*. 193
The embryo-sac of Aster Novæ-Angliæ. (With plates XV and XVI.)—*Chas. J. Chamberlain*. 205
Present problems in the anatomy, morphology, and biology of the Cactaceæ. *(Concluded.)*—*W. F. Ganong* 129
Noteworthy anatomical and physiological researches. 222
Some recent cell literature.—*J. E. Humphrey.*
Briefer Articles 229
Vitality of Marsilia quadrifolia.—*C. R. Barnes.*
Aspidium simulatum.—*Geo. E. Davenport.*
Dr. Joseph Schrœter.—*J. C. A.*
Collinsia bicolor.—*Alice E. Keener.*
Editorial 233
Current Literature 234
Notes and News 237

[ISSUED MAY 20.]

MADISON, WISCONSIN.
PUBLISHED BY THE EDITORS.

Tracy, Gibbs & Co., Printers, Madison, Wisconsin.

THE BOTANICAL GAZETTE

A Monthly Journal Embracing all Departments of Botanical Science.

ANNUAL SUBSCRIPTION, $3.00.

SINGLE NUMBERS, 30 CENTS.

The subscription price must be paid in advance. No numbers are sent after the expiration of the time paid for. No reduction is made to dealers or agents.

In Great Britain, 14 shillings.	In Germany, 14 marks.
Agent, W. P. COLLINS,	Agents, R. FRIEDLÆNDER & SOHN,
157 Great Portland St., London, W.	Carlstrasse 11, Berlin, N. W. 6.

The prices named include postage.

Subscriptions and business correspondence should be addressed to the **BOTANICAL GAZETTE, MADISON, WIS.**; money orders and drafts should be made payable to the BOTANICAL GAZETTE.

Separate Copies.—Contributors are furnished on request 25 separate copies of their articles (free) when 2 pp. long or more. Additional copies will be supplied at the following rates: For each 4 pages or less, per 100, $1.50; for each plate, per 100, $1.00. A less number at the same rate. Covers like GAZETTE, with title, $1.50 per 100, additional. ☞ *The number desired must be marked* **at the head of the MS.**, *as none will be printed unless ordered.*

Manuscripts.—Contributors are requested to write scientific and proper names with particular care, and in citations to follow the form shown in the pages of the GAZETTE. Manuscripts may be sent to any one of the editors.

Illustrations and advertisements.—Articles requiring illustrations and correspondence about advertisements should be addressed to **J. C. ARTHUR, Purdue University, Lafayette, Ind.**

Missing Numbers.—Will be replaced *free* only when claim is made within 30 days after receipt of the number following.

[Entered at the Post-office at Madison, Wis., as second-class postal matter.]

In the June number will appear:

Contributions to the embryology of the Ranunculaceæ, by PROF. D. M. MOTTIER, *Indiana University, Bloomington.*

Musineon of Rafinesque, by PRES. JOHN M. COULTER, *Lake Forest University*, and MR. J. N. ROSE, *Washington, D. C.*

The botanical work of the government, by PRES. JOHN M. COULTER, *Lake Forest University.*

A discussion of nomenclature, by DRS. B. L. ROBINSON, *Herbarium of Harvard University;* W. F. GANONG, *Smith College;* and ERWIN F. SMITH, *Washington, D. C.*

The development of botany in Germany during the nineteenth century, *will be concluded.*

BOTANICAL GAZETTE

MAY, 1895.

The development of botany in Germany during the nineteenth century.

EDUARD STRASBURGER.

AUTHORIZED TRANSLATION BY GEORGE J. PEIRCE.

[The following paper was published in 1893 in the second volume of the great and expensive work, *Die Deutschen Universitäten*, which the German Imperial Government prepared for the World's Columbian Exposition at Chicago. Its translation and publication in the BOTANICAL GAZETTE have been authorized by Professor Strasburger and by the Editor of the government publication in which it appeared. Since it forms the only supplement, so far as I know, to Sachs's "History of Botany," and brings the account to date, I have thought it would be extremely useful to American and English readers. The original publication is costly and not generally accessible, another reason for presenting it in English.—G. J. P.]

During the last half century Germany has been accorded a very high rank in botanical science. One evidence of this is that the botanical establishments of the German universities are able to congratulate themselves on being the resort of foreign botanists. It may safely be asserted that the impulses which, during this century, have carried botanical investigation into new lines, have been given in many cases by the teachers at the German institutions of learning. In purely systematic work England has held first place until recently, and now Germany is becoming her more and more successful competitor. The objects of botanical inquiry, like those in other departments of biology, were greatly affected by the theory of selection emanating from England, which Germany quickly accepted. For the theory of descent, which found fresh support in Darwin's theory of selection, the ground was well prepared, so far as botany was concerned, by Hofmeister's researches in comparative morphology.

The first decades of this century were devoted mainly to anatomical investigations, but at that time attention was

given almost entirely to the fully developed tissues and the solid cellular framework of plants. In the course of these researches the methods of investigation were improved, and observations were no longer made on crushed or torn objects, but on delicate sections. The improvements in microscopes, which were made at the same time, greatly aided such studies; and when one compares the figures made in successive decades, one sees how great have been the advances in the graphic reproduction of the objects seen. One may say that this sort of investigation of the plant body reached its fullest development during the thirties, and that the works of HUGO VON MOHL (of Tübingen, died in 1872) are its crowning achievements. By M. J. SCHLEIDEN (1839–1863 in Jena, died in 1881) the life history of plants was brought into prominence and declared to be the necessary foundation of every morphological conception. Schleiden's works were also the first in which the attention of investigators was directed to the cell-contents. From this time on, morphological study with the microscope began to develop in different directions; one which, at the same time that notice was taken of the development, was but the continuation of the former phytotomic researches, anatomy strictly so-called; another, which concerned itself with the cell-contents, cell-structure, and the origin of the tissues, histology; the third, whose main problem was the development of the members of the plant body, the solution of which was sought by the study of growing points and of forming embryos. These three directions were indicated by Schleiden and NÆGELI (of Freiburg and Munich, died in 1891), in part by the latter only. A contemporary of Schleiden, Nägeli excelled him in keenness of understanding, in critical power, and in observing faculty.

Nägeli's researches into the growth of the stems and roots of vascular plants, published in the year 1858, laid the foundations of plant-anatomy. In this work Nägeli developed from the purely morphological standpoint a classification of tissues, distinguished various types of growth, and finally traced the course and arrangement of the fibro-vascular bundles in the plant. Phytotomic investigation with morphology as the foundation was carried on by H. von Mohl, Schacht, Dippel, Frank, Count Solms-Laubach, Sanio, and von Hanstein. Of these, SANIO (a teacher in Lyck, in East Prussia, died in 1891) undoubtedly won most credit. His work, without the

least loss in value, was put somewhat into the background in 1877, when the "Vergleichende Anatomie" of A. DE BARY (at Freiburg, Halle, Strassburg, died in 1888), appeared. This book codified and extended our knowledge of plant anatomy, and established a nomenclature of the tissues which still holds good. The anatomical work of L. KNY (of Berlin), E. STRASBURGER (of Jena, now in Bonn), and H. SCHENCK (docent in Bonn) followed essentially the same direction.

Many celebrated investigators in other lands took part in the development of morphological phytotomy, but it is not for me to describe their labors here, since this can be a historical survey of the work of the German universities only, especially those of the German Empire. This limitation will naturally cause the sketch here presented to be very incomplete, and may even make it appear as though credit were given to the investigators at German institutions of learning for work in which they were merely participants with others. This possible reproach must be met by the frank acknowledgment of the limitations here necessary.

In contradistinction to that form of anatomy in which comparative morphological and, of late, in conseqence especially of Strasburger's work, phylogenetic characters were considered the essentials in estimating the importance of the tissues, there developed in the seventies the so-called physiological-anatomy. This new direction was given to the subject by SCHWENDENER (of Tübingen, now of Berlin) in his book "Das mechanische Princip im anatomischen Bau der Monocotylen," which was published in 1874. Schwendener's pupils work along this line, and the most talented of these, G. HABERLANDT (of Graz), attempted in 1884 to give a complete outline of physiological plant-anatomy.[1] Physiological plant-anatomy is a part of physiology, and as such it has led to conspicuous achievements. It has brought confusion into anatomy only in so far as it has attempted to establish its conceptions in the place of strictly morphological ones.

THEODOR HARTIG (Berlin, Brunswick, died in 1880), whose peculiar terminology rendered an understanding of his conceptions so difficult that they were often less regarded than they deserved, went his own way in the study of anatomy, though following essentially the morphological direction. Indeed, Th. Hartig was a keen observer, and many a discovery since made can be pointed out in his writings as a fact already known to him.

[1] Physiologische Pflanzenanatomie. Leipzig, 1884.—G. I. P.

The cell-theory which Schleiden set forth in 1838, soon showed itself to be defective, but it is nevertheless of great historical importance. It stimulated Th. Schwann to the microscopical investigations of the similarity in the structure and growth of plants and animals, which he published one year later; and it directed the attention of all to the contents of the cells. Soon Nägeli published his, for that time, remarkable researches into the formation and division of cells. H. Mohl also turned his attention to this new direction, exhaustively studied the appearance which the nitrogenous portions of the cell-contents display during their constant changes of form, found that they present for the most part the phenomena of streaming, and gave to them the name of *protoplasm*. In the year 1850, FERDINAND COHN (of Breslau) emphasized the identity of the contractile substance of animal cells with the protoplasm of plants, and this induced the zootomist Max Schulze, of Bonn, in 1863, to extend the name of protoplasm to the living substance in the whole organic kingdom. The minute structure of vegetable protoplasm was described by N. PRINGSHEIM (Jena, Berlin [2]) in a way which is valuable to this day, and our insight into its nature was thereby greatly advanced. On the other hand no investigations into cell-formation and cell-division, as they were conducted by Nägeli, Mohl, Pringsheim, Hofmeister, and others, could go beyond a certain point, and necessarily led in part to fallacious conclusions, so long as they were conducted on living, or at least not "fixed" objects. E. Strasburger was the first to conduct such investigations on suitably hardened material. In the first edition of his "Zellbildung und Zelltheilung" in 1875, this method was systematically employed. Combined with the most extended investigations, which included the whole vegetable kingdom, and parts of the animal kingdom as well, this method led to general results which applied to the whole organic realm. This publication stimulated manifold researches, especially by the animal histologists, which extended, and in various ways corrected, the statements of its author, without, however, impairing the value of the most important results therein set forth. Strasburger himself, in the third edition of the book in 1880, was able to trace back free cell-formation to the general phenomena of the origin of cells; and in subsequent

[2] Died in Berlin, October 6, 1894.—G. J. P.

publications, he pursued the further development of the question. While the material studied for the first publication of the book was nearly all unstained, in further observations stained objects were used, and in the course of these investigations microscopic technique made not the least important of its advances.

From the moment when the attention of investigators was turned to the contents of cells, further researches into the nature of the bodies enclosed within the body of the cell itself had to be undertaken. Special studies of starch-granules, chlorophyll bodies, aleuron-grains, and the like, were made by Nägeli, J. Sachs, Th. Hartig, W. Pfeffer, W. Schimper, Fr. Schmitz, Arthur Meyer, Zimmermann, and others. In this series the discovery of the amylogenic bodies by W. SCHIMPER (of Bonn), was of fundamental importance.

Nägeli's mathematical talent, and his desire to fathom the causes of these phenomena, led him to deduce from the phenomena of swelling, double-refraction, growth, and from the visible structure of stratifications and striations, a theory as to invisible structure of organized bodies. The stratification of cell-membranes has since been shown by DIPPEL (Professor at the Polytechnic School in Darmstadt), FR. SCHMITZ [3] (in Greifswald), Strasburger, NOLL (docent in Bonn), and KRABBE (docent in Berlin), to be due to growth by apposition. Although the theory of growth by intussusception is no longer held in the sense in which Nägeli conceived it (for the double refraction of organized bodies has presumably other causes than those assigned by Nägeli), yet his micellar theory remains as a brilliant conception which must hold a high place in the history of our science. Recently Wiesner (of Vienna) has put forth other views as to the elementary structure and the growth of living-substance, which are quite opposed to those of Nägeli. On the other hand, G. BERTHOLD (Göttingen) has sought by his studies in the mechanics of protoplasm [4] to explain by physical causes the structure, the formation, and the movements of the body of the living cell. Similar investigations of the zoological aspects of the question have been published by Bütschli and by the physicist Quincke. The chemical constituents of the living cell have occupied the attention of REINKE (Göttingen, now in Kiel), ZACHARIAS (of

[3] Died January 28, 1895.—G. J. P.

[4] Studien über Protoplasmamechanik; Leipzig, 1886.—G. J. P.

Strassburg), and especially of FRANK SCHWARZ (at the Forestry Academy at Eberswalde).

The tendency to give a mathematical aspect to observed phenomena controlled Nägeli's investigations of apical growth, which he published in 1845. In a similar way, but with independent broadening and deepening of the problem, W. HOFMEISTER (Heidelberg, Tübingen, died in 1877), followed the course of development of the organs of the plant from the processes of division which take place in growing points and embryo and in 1851 published his now famous comparative researches on the germination, development, and fruiting of the higher cryptogams, and the formation of seeds in the Coniferæ. Those researches laid the foundations for a phylogeny of the vegetable kingdom ten years before the appearance of Charles Darwin's "Origin of Species." The value of a knowledge of development, of morphological comparisons based on exhaustive investigation, was thus set in a new light, and a broad field was opened for further study. That many single statements in this book were erroneous does not in any way diminish its value, for this rests on the broad foundation of the whole work.

Hofmeister's remarkable ability to comprehend the homologies of the most remote divisions of the vegetable kingdom, gave permanent value to his morphological comparisons. At the same time, the gulf which seemed to separate the cryptogams from the phanerogams was bridged by Hofmeister's discoveries, and the processes which take place in the formation of the embryo among phanerogams, were set in their proper relations with the alternation of generations among the higher cryptogams. In the field thus opened by Hofmeister, Pringsheim labored with similar objects in view, but with limitations of the problem, and his achievements are now classical in every detail. Gaps in our knowledge have been closed by the valuable contributions of METTENIUS (Leipzig, died in 1866), CRAMER (of Zürick), von Hanstein, Kny, and Strasburger. LEITGEB (of Graz, died in 1888) devoted to the Hepaticæ seven full years of the most careful study along similar lines. The value of these researches, which laid bare the origin, development and homologies of the organs of the plant, will be permanent, despite the fact that the early investigations, inaugurated by Nägeli, of the processes of division

which take place at the vegetative point have lost the importance which was once attributed to them; for Sachs has shown that the arrangement of the elements at vegetative points is not of morphological significance, but is controlled by mechanical conditions.

Schleiden's investigations into the formation of the embryo of phanerogams, which date from the year 1837 on, led him curiously astray. He considered that the embryo originated from the tip of the pollen-tube, and that the ovule was merely the place in which it was further to develop. If this were so, then there would be no sexuality in plants, and a comparison with the phenomena of fertilization in the animal kingdom would be quite out of the question. Schleiden's views found warm defenders, but in 1849 Hofmeister came out clearly in opposition to him, in a very comprehensive work. (Amici, in Italy, had already in 1842, taken such a stand). Hofmeister proved beyond controversy that the egg (germinal-vesicle) was already formed in the ovule, and that it was fertilized by the contents of the pollen-tube. He did not arrive at the current notion of the structure and phenomena of the sexual apparatus. These were first made clear by Strasburger in 1877. In the same paper Strasburger showed also that the hitherto supposed cases of parthenogenesis among phanerogams were due to the adventitious formation of embryos by non-sexual branching of the nucellar tissue into the cavity of the embryo-sac. Since the number of such branchings is indefinite, it is at once evident why, in the supposed cases of parthenogenesis, polyembryony is so common. Two years before (1869) it had already been demonstrated by Strasburger that the so-called corpuscula of the Coniferæ are true archegonia, and that their contents represent a single egg.

In 1880 KARL FRIEDRICH SCHIMPER (a scientific man who occupied no public office, and who died in 1867, at Schwetzingen) established the new theory of phyllotaxy, which attracted due notice, and became further developed and carried to formal completion in the writings of ALEXANDER BRAUN (Freiburg, Berlin, died in 1877). This theory assumed, in consequence of Braun's idealistic conception of nature, the form of abstract principles which controlled the processes of development in the body of the plant. Hofmeister was the first, in 1868, to attempt to explain the observed regularity in the

arrangement of members on a common axis, and their spiral sequence, by reference to definite mechanical causes. The mechanical basis for the theory of phyllotaxy was completed in Schwendener's writings (1878), which showed that mechanical and geometrical conditions, especially the pressure exerted upon one another by the young members forming on the common axis, control the regularity of their positions in relation to each other. In the same way K. SCHUMANN (Custodian in the Botanical Museum at Berlin) is now attempting to explain the arrangement of floral organs.

Closely akin to Braun's work, in that he established certain types, which, however, he considered to be phylogenetically the true starting points of later variations, W. EICHLER (Graz, Kiel, Berlin, died 1887) published in 1875 and 1878 the two volumes of his "Blüthendiagramme." These are founded on general comparative investigations of the mature form, supplemented by a study of the development. From a similar stand-point PAX (Custodian in the Botanical Garden at Berlin), wrote his "Handbuch der allgemeinen Morphologie der Pflanzen" which appeared in 1890. K. GOEBEL (Rostock, Marburg, Munich), on the other hand, tried in his "Entwickelungsgeschichte der Pflanzenorgane," published in 1883, to be independent of the morphological ground-plans, to consider the distinct members of the body of the plant for themselves, and to be directed in their comparison only by the homologies. Development and comparative morphology are to him the most important aids in organography.

Although the philosophical element in Braun's most important work, concerning rejuvenation in nature, published in 1851, is contrary to the principle of cause, which is now the basis of scientific thought, yet this work still holds attention because of the freshness of its descriptions and the affectionate absorption of the author in his problem. For this reason the work contributed no slight stimulus to the further study of the lower cryptogams, especially of the Algæ. Thuret performed certain experiments in 1853 which demonstrated the sexuality of the *Fucaceæ*, but he attributed fertilization to the effects of the contact between spermatozoid and egg. Pringsheim was the first to show, in his researches published in 1855, that in generation "a mingling of the whole spermatozoid mass with the fructifying sphere takes place." Important works by Pringsheim, which made clear the whole

development of various groups of algæ, and of the alga-like *Saprolegniæ* followed in subsequent years. Other valuable researches by Ferdinand Cohn, de Bary, PFITZER (Heidelberg), Goebel, Berthold, Fr. Schmitz, Reinke, and other German investigators supplemented them, but in 1869 Pringsheim made another remarkable contribution to this field of knowledge by his discovery of the copulation of gametes (zoospores).

Early in the sixties the impulse to a reform in the study of the Fungi was given by de Bary in Germany, while Tulasne had already done the same in France. It was de Bary who, more than any one else, perfected the methods of investigating the Fungi, directed researches into decisive lines, and laid the foundations for the results which this department of knowledge was soon able to show. After him O. BREFELD (Münster) took the lead by his achievements in this field, and since 1872 has devoted himself to studying the development of fungi, beginning with a single spore and tracing its development to the end. Brefeld's methods, extended and adapted to the field of bacteriology, have produced great results. De Bary first effected the artificial infection of a host by a fungous parasite, but Brefeld was the first to succeed in cultivating typical parasites in nutrient solutions, thus making them saprophytic. By de Bary's investigations, our notions of the alternation of generations among the Fungi were brought within the true limits, while Brefeld leveled the ground for the construction of a natural classification of the Fungi, and considerably limited the statements as to sexual differentiation in this group.

The demonstration of the fact that lichens are symbiotic double organisms, depending upon the union of ascomycetous (rarely hymenomycetous) fungi with algæ, attracted general attention. In 1860 and 1868, in the first two parts of his researches into the lichen thallus, Schwendener declared the gonidia to be the terminal cells of short lateral branches of the hyphæ. In 1866 de Bary led up to the true idea of the lichen thallus in the gelatinous lichens, and spoke the words which solved the whole problem and brought about the right conception of all lichens. This final step was taken by Schwendener in the supplement to the last part of his "Flechtenstudien," and was repeated still more decisively in his "Algentypen der Flechtengonidien," published in 1869. In basing this conception on studies in development, STAHL (of Jena) has

won most credit in Germany. Further questions as to the presence of sexes in lichens, and as to the structure and development of their organs of fructification, have been pursued especially by Stahl, FÜNFSTÜCK (docent in Stuttgart), and G. Krabbe. Alfred Möller succeeded in Brefeld's laboratory in cultivating lichens saprophytically, and without the algæ, in nutrient solutions.

The appearance in 1865 of "Die Experimentalphysiologie der Pflanzen," by JULIUS SACHS (Freiburg in Baden, Würzburg), marked an epoch in the development of vegetable physiology. The work at once restored vegetable physiology to its place at the center of scientific research, whence it had been pushed aside by the increased interest in anatomical investigation. The work did this the more successfully since it contained not merely a clear and well arranged review of the achievements of former times, but also the fundamental investigations of its author which extended to nearly all of the divisions of physiology. The number of physiological researches which were then carried on by Sachs himself, and by his pupils, grew from year to year, and were for the most part published in the Arbeiten des botanischen Instituts zu Würzburg. These researches concerned all divisions of physiology, but especially the relations of plants to those external forces which operated upon them. PFEFFER (Basel, Tübingen, Leipzig) developed especially the physical side, and during the last twenty years has produced a series of most remarkable works. His investigations of the chemotactic movements awakened special interest, for they explained, at a single stroke, as the attraction of definite organisms by chemical substances, the until then enigmatical influence which the sexual products exert, even at a distance, upon each other. His "Handbuch der Pflanzenphysiologie," which appeared in two volumes in 1881, at once became indispensable to every botanist. GEORG KLEBS (of Basel) has since then especially developed the physiology of the vegetable cell; phototactic phenomena were exhaustively studied by Strasburger and Stahl; W. DETMER (of Jena), and W. Schimper have distinguished themselves in the field of physiology of nutrition, and many valuable contributions to our knowledge of this subject have been made by B. FRANK (professor at the Agricultural College in Berlin). We are indebted to A. HANSEN (of Giessen) for good chemico-physiological contributions.

Besides Sachs, ROBERT HARTIG (of Munich), Schwendener and Strasburger have especially interested themselves in the problems of the movement of water in the plant; while ALFRED FISCHER (Leipzig), and others have been concerned with the transfer of food-materials. Concerning the physiological phenomena of irritability, in addition to the fundamental labors of Sachs, the researches of WORTMANN (professor at the Academy in Geisenheim), of VOCHTING (Basel, Tübingen), and especially of FR. NOLL (docent in Bonn), have found well merited respect.[5] An attractive presentation of our entire physiological knowledge was given in Sachs's "Vorlesungen über Pflanzenphysiologie,"[6] the first edition of which was published in 1882. The phenomena of the irritability of the living substance were there thoughtfully set forth, and their importance in the true estimation of the phenomena of life clearly elucidated.

Our knowledge of the reproductive processes has gained merely a firm morphological basis. Strasburger especially has contributed to this during recent decades. The physiology of reproduction is still, for the most part, on speculative ground; but it was notably advanced in 1884 by Naegeli's mechanico-physiological theory of descent, in which the idioplasm theory was first formulated. Naegeli's observations on the production of bastards, on the conditions for the appearance of species and varieties, and his studies, extended through years, of the intermediate forms among the Hieraciums, are to this day important contributions to the phenomena of genera and development.

Thanks to Darwin's classical work on the arrangements for pollination among the orchids, the attention of students was directed to a very remarkable book by Christian Konrad Sprengel which, published in 1793, remained quite unnoticed and had practically disappeared. In all parts of Germany, workers turned their active attention to this subject, and in consequence, Sprengel's assertions were generally confirmed, often extended, and in many essential points given their correct significance. FR. HILDEBRAND (Freiburg in Baden) was the first to distinguish himself in this direction; but HERMANN MÜLLER (teacher in Lippstadt, died in 1883)

[5] No one will doubt that Pfeffer's name was only unintentionally omitted, and that it deserves a prominent place in this list.—G. J. P.

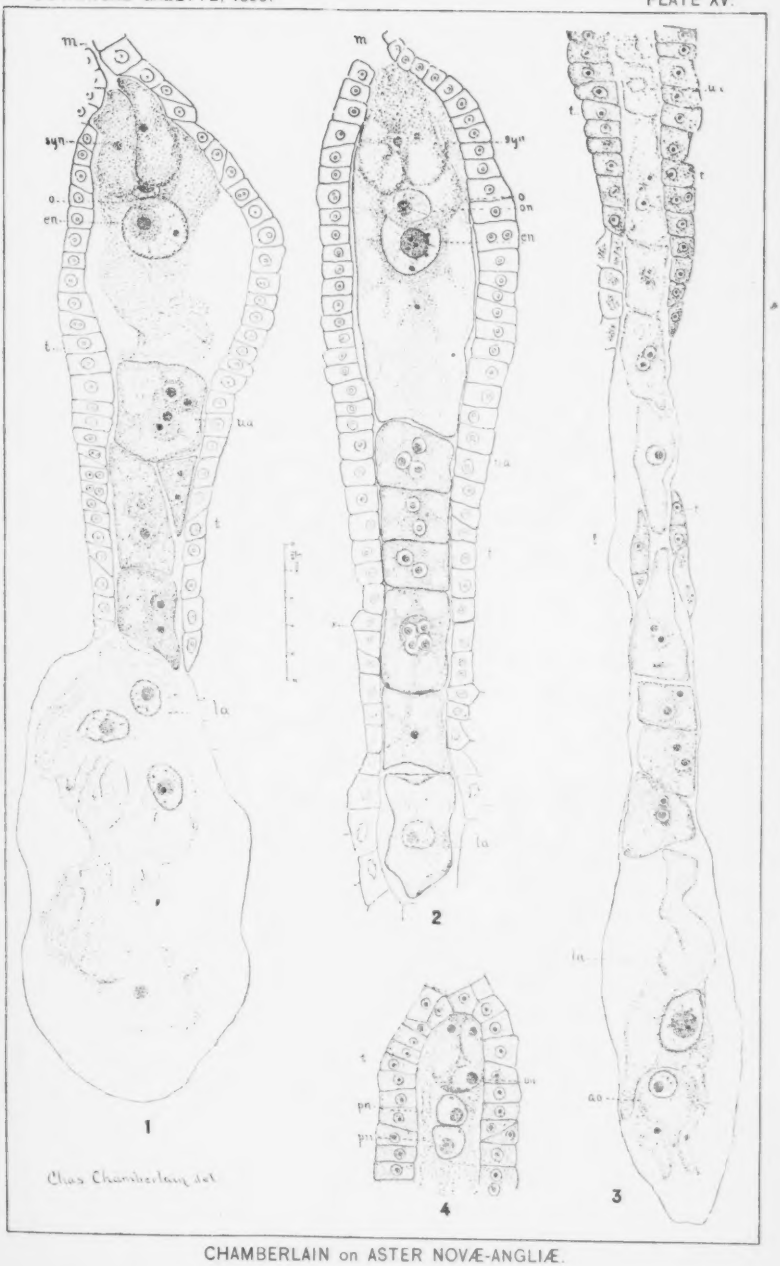
[6] Translated and published in English in 1887.—G. J. P.

especially did so in the numerous writings in which he described the arrangements for pollination in flowers. This is still a promising field for investigation, and busies many students, merely to name whom space here forbids.

The investigation of the phenomena of pollination of flowers, and of the striking adaptations between flowers and insects, which here present themselves to students, greatly promoted the study of adaptations in general. These are now comprehended under the general name of biology but, under the name of ecology or the study of adaptations, would better form a part of physiology. We are indebted to Hildebrand, Stahl, VOLKENS (docent in Berlin), but especially to Goebel and Schimper, for valuable contributions to this subject. The last named has contributed material of remarkable value bearing upon the problems of plant-geography. A distinct field of physiology was opened by Vöchting's striking work on the apex and base of plant members, on the inner polarity of the plant body, and on the related phenomena of regeneration.

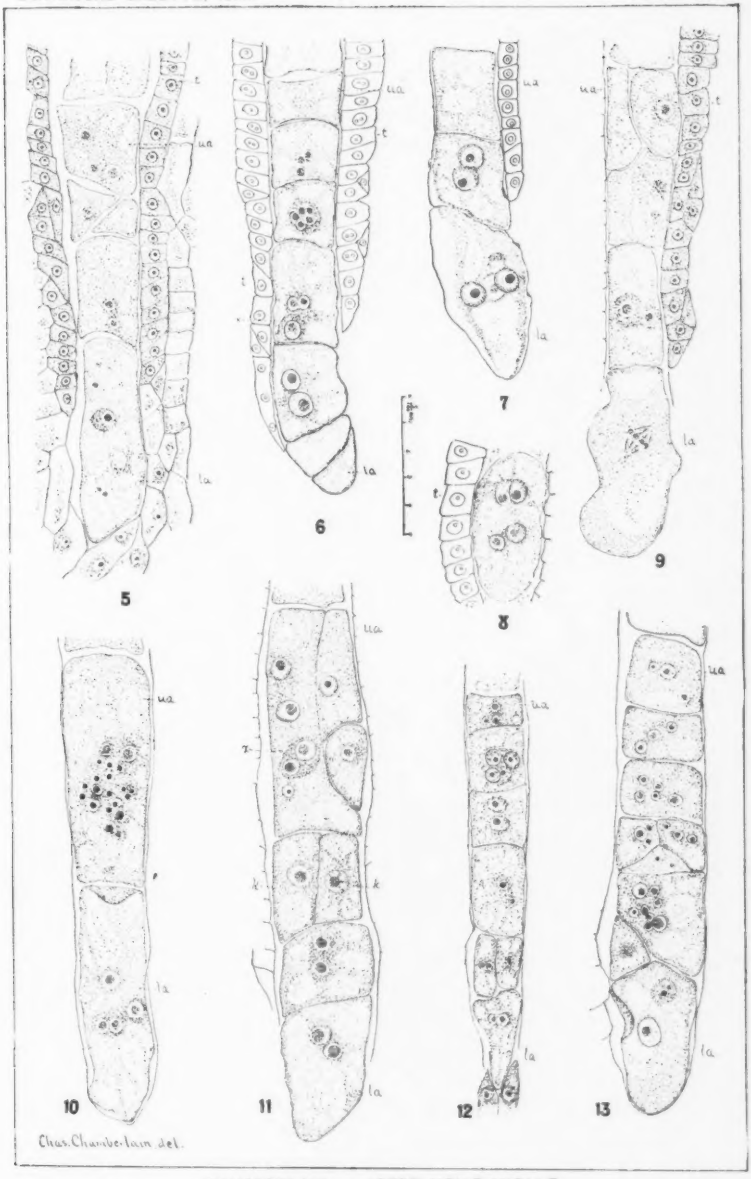
[*To be concluded.*]

Bonn, Germany.



CHAMBERLAIN on ASTER NOVÆ-ANGLIÆ.

THE
JOHN CRERAR



CHAMBERLAIN on ASTER NOVÆ-ANGLIÆ.

THE
JOHN CREAR

The embryo-sac of Aster Novæ-Angliæ.

CHAS. J. CHAMBERLAIN.

WITH PLATES XV AND XVI.

In its early history the ovule of *Aster Novæ-Angliæ* presents little to distinguish it from the well known types of Compositæ. Its anatropous character is already obvious, and its only integument is almost as conspicuous as the nucellus itself, when the archesporium appears. This cell undergoes the expected divisions and, of the four resulting cells, the one farthest from the micropyle is usually, but not always, destined to become the embryo-sac.

Development of the macrospore.

In tracing the early stages in the development of the embryo-sac, I employed methods suggested by Auerbach's researches.[1] He emphasized the significance of the fact that if a preparation containing both spermatozoa and ova be stained with some combination like Biondi-Ehrlich, the nuclei of the spermatozoa take the green while those of the ova prefer the red. He proposed the terms, cyanophilous and erythrophilous to indicate these preferences. Since 1891 a few attempts have been made to obtain analogous results in plants. It is not very difficult to differentiate the nuclei of the pollen grain. The generative nucleus takes the green while the vegetative prefers the red, but I was not able to find a single green nucleus in the embryo-sac. The mother cell of the embryo-sac and also the four cells resulting from its division, stain red. At the first division of the nuclei of the embryo-sac the resulting nuclei stain red. It might be noted, however, that the nucleus which produces the egg apparatus sometimes differs in appearance from the one which gives rise to the antipodal cells. In all the stages which precede fertilization the nuclei stain alike, even the two polar nuclei which unite to form the endosperm-nucleus. Since some have imagined this fusion to be a sexual process, I took particular care in staining, but

[1] AUERBACH, LEOPOLD:—Zur Kenntniss der thierischen Zellen Sitzungsb. der Kgl. preuss. Akademie der Wissenschaften, 26 Juni, 1890, and "Ueber binen sexuellen Gegensatz in der Chromatophilie der Keimsubstantzen," in the same journal of 25 Juni, 1891.

even when the pollen grains and active glands were taking a brilliant green, the fusing nuclei persisted in taking only the red, thus indicating that the fusion has no relation to a sexual process.

With the formation of the endosperm-nucleus the embryo-sac completes its preparations for fertilization. All my figures, except fig. 3, are drawn from embryo-sacs in which the endosperm-nucleus is already formed.

The mature embryo-sac.

The mature sac is surrounded by a beautifully distinct wall of tapetal cells, *t*, figs. 1, 2 and 3, filled withdense protoplasm remarkably free from vacuoles. The egg apparatus usually occupies the micropylar sixth of the sac and displays that reluctance to vary which characterizes structures directly concerned in reproduction. Indeed, there is such uniformity that one knows beforehand just where to focus his mind and microscope to catch the elusive outlines of the synergidæ and micropylar portions of the ovum.

The egg occupies from one-half to four-fifths of the entire diameter of the sac. It well deserves the name, oösphere, for it is often a perfect globe. Usually, however, the egg is pear-shaped, with the smaller end nearest the micropyle; but whatever its shape, there is almost invariably a large vacuole, occupying the greater part of the interior. Below the vacuole in a dense mass of protoplasm, is the egg-nucleus.

The two synergidæ generally fill the entire diameter of the sac. They are somewhat ovate in form and extend from the micropyle to about the middle of the ovum. Their nuclei do not seem to have any favorite position, for they are found, sometimes at one end of the cell, sometimes at the other, but perhaps, more frequently, near the middle. In a few specimens I found the nuclei doubled but never found more than two synergidæ. In two or three cases the principal vacuole was found in the micropylar end, but its usual position is at the opposite extremity. Like the egg, the synergidæ are not protected by any membrane.

As one glances at the mature embryo-sac, its most conspicuous feature is the endosperm-nucleus. Its nucleolus is large, dense and apparently homogeneous, if we except one or more globules which are invariably present. When xylol is used to precede the paraffine, these globules become extremely refractive and seem to be composed of oil. Connect-

ing the nucleolus with the nuclear membrane are delicate radiating filaments. Fig. 2 represents a typical egg-apparatus with its two synergidæ and ovum. The large endosperm nucleus lies just below the egg.

In tabulating measurements of various features of the embryo-sac, I was so impressed by the uniformity in the size of the nucleoli of the egg-apparatus and secondary nucleus that I will give some of the measurements here. The length of the mature sac varies from 250 to 300μ, its diameter at the egg from 35 to 45μ, the diameter of the egg from 22 to 28μ, that of the egg-nucleus from 10 to 13μ, and that of the endosperm-nucleus from 16 to 20μ. The nucleoli, however, presented an unbroken uniformity, the endosperm-nucleolus measuring almost invariably just 10μ, the egg-nucleolus 6μ, which occasionally inceased to 7 or 8μ. The nucleoli of the synergidæ usually measured 4μ, although in a few cases, they reached a diameter of 5 or 6μ.

Development of the antipodal region.

The uniformity which characterizes the egg-apparatus and secondary-nucleus is left behind when we descend to the antipodal region. For this very reason the antipodal cells of *Aster Novæ-Angliæ* furnish an exceptionally interesting field for investigation. The text-books would lead us to expect just seven cells in the mature embryo-sac, and indeed, in the case before us, the sac is often found in this stage, with its egg, two synergidae, secondary-nucleus and three antipodal cells. But previous to the formation of the secondary-nucleus, the antipodal cells frequently enter upon a career of development which can hardly fail to attract attention. My results here do not agree very well with those of Martin,[2] published in this journal. He finds no walls on these cells, finds no cross partitions, never finds more than four antipodal cells and those never arranged in a single longitudinal row. I find that even when there are only three antipodal cells, they form membranes and are usually arranged in a single longitudinal row; also that when there are more than three antipodal cells, one or more cross partitions are found. From my preparations of Aster and Solidago I should conclude that cell walls, cross partitions and longitudinal arrangement

[2] Development of the flower and embryo-sac of Aster and Solidago. Botanical Gazette **17**: 406. D. 1892.

were the rule in these two genera. My sections of embryo-sacs, which were just approaching maturity, resemble Martin's figures and lead me to suspect that his conclusions have been drawn from material in an early stage of development.

Strasburger has noted that there are sometimes more than three antipodal cells, and Mottier[3] figures a case in which each of the three cells has divided.

In rare cases I found just three antipodal cells, each with a single nucleus, three cells with doubled nuclei were not quite so rare, while the condition represented in the figures was not at all uncommon. In fig. 2 we have six antipodal cells, arranged in a single longitudinal row, with the divisions approximately in the same plane. Fig. 11 shows seven antipodal cells which present more complexity in their arrangement. Fig. 13 has nine antipodal cells with still another variation in the plane of division. Fig. 3 goes a step farther and displays thirteen cells. The first three of these cells, of course, arise from free cell formation, but when the number exceeds three, the extra cells are produced by cell division with the formation of partitions. If the partition is not formed at the first division of the nucleus, as in fig. 11, *k*, I am inclined to think that it will not be formed later, at least I have not seen anything which would lead me to believe that partitions are formed after the nuclei have begun to multiply, as in fig. 10.

I am well aware that the doubling of nuclei is not unusual in these cells, but neither my reading nor my preparations of other embryo-sacs foreshadowed the condition represented in fig. 13 where we have thirty nuclei in a single section. Fig. 10 shows twenty nuclei in one section of a single cell. The occurrence of mitotic figures proves that these nuclei multiply by indirect division, but whether they multiply by fragmentation also, I am not prepared to say, although some of the cases figured would suggest such a possibility.

The homology of the antipodal cells has long been a subject for controversy. Without reviewing theories, it seems to me that Strasburger was correct in making them homologous with the prothallium of the gymnosperms. This homology seems sound when we compare their origin with that of the gymnosperm prothallium, but the gymnosperm prothal-

[3] On the embryo-sac and embryo of Senecio aureus L. Botanical Gazette 18: 245. Jl. 1893.

lium proves its title to the name by bearing archegonia. The bearing of archegonia would vindicate the claim of the antipodal cells in the same manner, but my reading has failed to furnish a single instance of such a phenomenon. A glance at my figures will show that the antipodal cells are not all alike, the lower one sometimes differing decidedly from the others. It is often much larger than the rest, it differs in the density of its protoplasm, appearing as if it had increased much more rapidly in size than in substance, and its nuclei resemble the endosperm-nucleus rather than the nuclei of the other antipodal cells. Figs. 1, 2, and 3 illustrate various forms of this cell with its large nuclei. The behavior of this cell recalls the free cell formation which occurs in the early history of the macrospore. This antipodal growth breaks through the layer of tapetal cells which surrounds the embryo-sac, and, continuing its development sometimes to an extent equalling half the original length of the sac, exerts a destructive effect upon the cells of the adjacent tissues. The mere tendency toward further development manifested by the antipodal cells is worthy of careful consideration.

I desire to call particular attention to the lower cell in fig. 3. I feel positive that I have discovered in this cell a veritable oösphere. It has precisely the appearance of the ordinary oöspheres of *Aster Novæ-Angliæ*, even to the position of its nucleus and vacuole and the distribution of its protoplasm. Furthermore, it has no cell membrane, thus differing in another important particular from the usual antipodal cell. It would seem that after the nucleus had divided, one of the daughter-nuclei had surrounded itself with protoplasm and become free, just as the ordinary oösphere originates and separates itself from the surrounding protoplasm of the macrospore. The fact that nuclei of other antipodal cells sometimes surround themselves with protoplasm in a way which recalls the formation of the ordinary oösphere, makes this theory seem possible. Figs. 2 and 6, *x*, furnish examples of such nuclei. It might be suggested that we have here a macrospore, in an unusual position, but a macrospore nevertheless. Whatever its real nature may be, its origin is not so uncertain. In some slides, the septum proves that this cell arises from division; in others, it may be one of the three original antipodal cells. In any case, its origin is not that of the macrospore, but that of the antipodal cell. The ap-

pearance of the accompanying bodies which present such a resemblance to synergidæ and cause a more complete likeness to the egg-apparatus of the other end of the sac, is probably accidental. This figure, like the other figures of the plates, was drawn with an Abbé camera and Zeiss 2^{mm} immersion lens, but the figure fails to show the extent of the resemblance. Lest it might be imagined that I have inverted the embryo-sac and mistaken the endosperm nucleus for the nucleus of this cell, I have drawn in fig. 4, the egg-apparatus of this same sac. It is to be noted here that all this development of the antipodal region has preceded the fusion of the two polar nuclei (fig. 4 *pn*) to form the endosperm-nucleus. It might also be added that the length of this sac is double that of ordinary sacs.

Additional evidence will doubtless be demanded by many, but the frequent occurrence of this peculiar antipodal cell in *Aster Novæ-Angliæ* leads me to believe that other instances of this phenomenon will be discovered. Indeed, like the unnoticed centrosomes, they may even now be awaiting observation on the slides of earlier investigators. The more conservative may ask that the history of this alleged oösphere be traced at least a few steps further before they allow its right to the name. Let fertilization and the formation of an embryo be observed. It is to be regretted that my material was collected for the purpose of studying the earlier development of the embryo sac rather than the formation of the embryo itself, and consequently the search for another antipodal oösphere, to say nothing of these later stages, is necessarily deferred.

Since reading Strasburger's recent discussion of the periodic reduction of chromosomes,[4] I have been curious to know the number which prevails in the nuclei of these antipodal cells, but as my material was collected late in October, after several severe frosts, mitotic figures were very infrequent and I have not yet been able to obtain any reliable results. Guignard's statement, that in lilies the nucleus which gives rise to the egg-apparatus is constant in its number of chromosomes, while that which produces the antipodal cells varies, is of interest in considering this irregular region.

[4] On the periodic reduction of chromosomes in living organisms. Annals of Botany **8**: 281. Ag. 1894.

Other Compositæ.

In pursuing these studies, I have made preparations of several other Compositæ, and in Solidago especially I have found considerable irregularity in the number and arrangement of the antipodal cells, but in no other have I found such extensive variation as in *Aster Novæ-Angliæ*.

Methods.

Absolute alcohol, saturated aqueous solution of picric acid, and 1 per cent. chromic acid were used in fixing material for this work. The smaller heads were merely halved; the larger heads were cut into sections about one-eighth of an inch thick before placing in the fixing fluid. Picric acid gave as good results as the chromic. With either acid the fixing is complete in twenty-four hours. Picric material should be washed in 70 per cent. alcohol until all yellow color disappears. Chromic material should be washed at least twenty-four hours in cold water or twelve hours in warm. In either case the water should be changed frequently.

Xylol, followed by a mixture of xylol and paraffine was used to precede the paraffine bath. Rosen's method was also quite satisfactory. After dehydration it is briefly this: (*a*) equal parts of absolute alcohol and bergamot oil; (*b*) pure bergamot oil; (*c*) equal parts of bergamot oil and paraffine at 40° C; (*d*) soft paraffine; (*e*) hard paraffine.

All sections were serial. I did not find it necessary to cut thinner than 5 μ.

With the exception of a little material which was stained in bulk with alum carmine, all sections were stained on the slide. Delafield's haematoxylin, acid fuchsin, Bismarck brown and Biondi-Ehrlich are excellent stains for this work. After many slides have been rinsed in the distilled water jar, the water becomes deeply colored. Some slides left over night in this jar to await staining in the morning showed a striking differentiation. My most satisfactory staining was subsequently obtained in this way.

Summary.

1. (*a*) The early development of the macrospore of *Aster Novæ-Angliæ* differs little from described types.

(*b*) The formation of the secondary nucleus has no relation to a sexual process.

2. (*a*) The egg is sometimes spherical and sometimes pear-shaped.
   (*b*) The vacuoles and nuclei of the synergidæ vary in position.
   (*c*) There is a striking uniformity in the size of the nucleoli of the egg-apparatus and the endosperm-nucleus.
3. (*a*) The number of antipodal cells varies from two to thirteen. Six or seven are as frequent numbers as three.
   (*b*) The number of nuclei in an antipodal cell varies from one to over twenty.
   (*c*) The lower antipodal cell differs from the rest in size, density of its protoplasm, appearance of its nuclei, and in its effect upon the surrounding tissues.
4. The discovery of an antipodal oösphere in the antipodal region is an additional proof that the antipodal cells are homologous with the endosperm of the gymnosperms.

Acknowledgements are due Dr. John M. Coulter for his kindly encouragement and valuable suggestions during these researches.

University of Chicago.

Explanation of Plates XV and XVI.

All figures are drawn from sections of the embryo-sac of *Aster Novæ-Angliæ* and are magnified 407 diameters.

Abbreviations.—*ao*, antipodal oösphere. *en*, endosperm nucleus. *la*, lower antipodal cell. *m*, micropyle. *o*, oösphere. *on*, nucleus of oösphere. *pn*, polar nucleus. *syn*, synergidae. *t*, tapetal cells. *ua*, upper antipodal cell.

Description of figures.—*Figs. 1 and 2.* Sections through the entire embryo-sac. *Fig. 3.* Antipodal cells with an antipodal oösphere. *Fig. 4.* Egg-apparatus of Fig. 3. *Figs. 5–13.* Antipodal region showing variation in number of cells and mode of arrangement. Fig. 8 represents one of the middle antipodal cells.

Present problems in the anatomy, morphology, and biology of the Cactaceæ.

W. F. GANONG.

[*Concluded from p. 138.*]

The development of the flower is unknown, excepting for references by Goebel and others. It is likely to prove of great interest, and may throw light upon the relationships of the family, as it certainly will of the genera. Biologically it is equally unknown, Schumann, Goebel and Loew giving it but the barest reference. How is it fertilized? How generally are the stamens sensitive or the flowers dichogamous? Why sometimes so evanescent? Why are the flowers often so showy? Do they illustrate the principle of showiness in proportion to scarcity of insects? Do the colors contrast with the background simply, or do they attract particular groups of insects? How do the less showy Mamillarias thrive? Is self-fertilization common? By what animals is the dissemination of the fruit effected? How are the dry fruits of Echinocactus and some Opuntias scattered? In berries, what is the meaning of the white and red colors; do they simply contrast with the background, or do they attract specific animals? How are bristle-covered Opuntia berries eaten? Are they picked at by the bills of birds and neglected by mammals? The pulp has been found in several species to be formed chiefly by the funiculus of the seed, though the wall of the hollowed receptacle co-operates. The extremely "inferior" character of the ovary of Cactaceæ leads us to question whether there be a biological reason for it. If so, is it to be found in protection to the ripening ovary, or in utilization of the receptacle to help form an edible berry? In some species, as Goebel has shown, the seeds germinate in the fruit. What does this mean? How are such fruits scattered? Upon the surface of some fruits, new branches appear; do they occur when those fruits have seeds?

Species of Cereus often show a sudden crest, forming where the few ribs are replaced by very many. What conditions determine this? How does the vegetative point act in the transition? The stems of several genera often show a close

crowding together of the spine-clusters, suggesting that the stems shorten as roots sometimes do in the ground. Do they shorten, or is the crowding simply the result of the pressing together of the spine clusters as the curved ribs straighten out in growth? It is easy to see an advantage for the shortening, as it would allow of a considerable development of new green tissue each year without an equivalent lengthening of the entire stem, and condensation is always an advantage to them. Moreover, in some stems, when cut across, the central cylinder soon shrinks down, showing that it is exerting a shortening pull upon the other tissues. I have seen this very marked in *Mamillaria macrothele*.

In several genera, as Opuntia, Rhipsalis, Phyllocactus and Epiphyllum, flat shoots occur, differing somewhat morphologically. These are usually jointed, and the joints commonly represent a year's growth. An important question arises as to how the flattening has been produced, and this has lately been investigated by Vöchting[16] and Goebel.[17] The latter shows clearly that light exercises a direct (not intermediate through natural selection, etc.,) effect in causing the flat form and the growth of the tubercles in Opuntia, and the same probably holds good in other genera. Is it true in others and how widely? The cause of the jointing needs investigation. It is a common xerophilous character as seen in Euphorbias, Kleinia, etc. Is it primarily a growth condition or a characteristic acquired for biological advantage? In some cases at least it is utilized, for joints break off and are rolled away to start in a new place.

It is important to search for other modes of protection in addition to spines. Do any Cactaceæ have a rank odor making them unpalatable to animals? Lewin has recently proven[18] his earlier statement that *Echinocactus* (*Anhalonium*) *Lewinii*, a variety of *A. Williamsii*, contains a poisonous alkaloid,[19] and he shows also that four or five others including a Cereus and Mamillaria are likewise provided. But it is not proven that these forms are thereby protected from animals. Are they? And if so, how do animals know that they are poisonous? Is it by smell or sight? They show no warn-

[16] Pringsheim's Jahrbücher **26**: 483–494. 1894.
[17] Flora **80**: 96–116. 1895.
[18] Ber. der d. b Gesellschaft **12**: 283. 1894.
[19] See Havard, Bull. Torr. Bot. Club **22**: 117. 1895, where *A. fissuratum* and *E. Lewinii* are said to produce intoxication when chewed.

ing colors, and if animals are not in some way allowed to distinguish the poisonous from the harmless they would destroy the plants before discovering that they are poisonous, and the object of this mode of protection be defeated. Either the animals are warned, or else the presence of the alkaloid is incidental and not an "adaptation" to protection. Not only *E. Williamsii* and closely related forms, but also the species of Anhalonium are without obvious means of protection, unless the hard cuticle of the latter serves to this end. The flattened and roughened and gray colored upper surface of *A. fissuratum* and the fact that they live partly sunken in the earth suggest that they may be protected by their resemblance to the ground on which they grow. Are they? The exudation of nectar already mentioned is perhaps protective, and the arrangement of crystals in a sort of armor just under the epidermis of *Opuntia arborescens* (to be described below) is probably protective against snails. Are any others to be found in the family? A red color occurs on the under surface of Peireskia leaves, on young shoots of Cereus, etc., and on nearly all seedlings. Is this, as Stahl would suggest, associated with the presence of tannin or other distasteful substance, and hence of the nature of a warning color? Or is it in the seedlings a light-screen? The probability of some protection against too great light and heat has already been mentioned, and possibly the hairs, or even the hypoderma may assist in this,[20] but nothing positive is known about it. The investigation of the minimum, optimum, and maximum temperature points for some desert Cactaceæ would give results of great interest. There is reason to think that electrical currents are to be detected on the deserts.[21] Do plants show any relations to them?

The entire relation of form-conditions to climate requires more careful study.[22] Is condensation proportional to dry-

[20] See McFarlane's suggestion, Bot. Centr. **51**: 184. 1895.

[21] National Geographical Mag. **4**: 171. 1893.

[22] As a basis for such study, the forms seem to fall into divisions about as follows. Goebel has traced the subject for the genus Opuntia.

a. *The branching, shrubby type*, little removed from the typical condition: the woody Peireskias.

b. *The unjointed column*
- upright
  - ribbed: Cereus, Pilocereus, etc.
  - tubercled: fleshy Peireskias, Cylindropuntiæ.
- creeping or deflexed: creeping Cereus and Echinocereus.

ness of climate?[23] If so, to means or extremes of dryness? It is to be noted that condensation can be more easily effected in the deserts than in cloudier climates, for the great cause in antagonism to condensation, *i. e.*, the need for a large spread of green surface, is here much less operative; for the slow growth of the plants requires less assimilation, and the intense and continuous light render possible a given annual amount of assimilation with a far smaller surface than is possible in cloudier climates. Hence condensation is absolutely easier to desert than other vegetation, and it may mean that the conditions are as not extreme as they appear judged by other standards.

Passing now to internal anatomy, the first great problem is to study it in relation to external conditions. As one views Cactaceæ in collections, he is continually surprised at the apparent lack of relation between the development of the tissues and the supposed habits of the plants. Some forms, such as Rhipsalis, Phyllocactus and some Opuntias, though not very xerophilous in habit (except in some cases where they possess xerophilous characters in common with other epiphytes), possess very strong cuticle, hypoderma and mucilage, while other marked desert forms, such as some Mamillarias, have very slight cuticle and no hypoderma. Even granting that the former cases are examples of survival of old xerophilous characters, how are the latter to be explained? Does tissue anatomy respond sensitively to changing conditions or does it not? Here, perhaps, better than anywhere else, is the opportunity to delimit internal growth conditions from those of "adaptation." A comparative anatomy of the family, studied in relation to life-conditions, and introducing comparisons with the characteristics of other desert families, would be of great value.

The very common collenchymatous hypoderma is proba-

c. *The jointed column* . . { upright; Cereus testudo.
deflexed: some Rhipsalis species.

d. *Phyllocladia*, two-ribbed flat shoots: Phyllocactus, Rhipsalis, Epiphyllum.

e. *Flattened ribless shoot* { lateral, on cylindric axis: Opuntia Brasiliensis.
all flattened: Platopuntiæ.

f. *Sphere form* (including short columns) { ribbed: Echinopsis, upright Echinocereus, Echinocactus, Astrophytum, Melocactus, etc.
tubercled: Mamillaria, Leuchtenbergia, Pelecyphora, Anhalonium.

[23] Noll has given (Flora 77: 353–356. 1893) exact data on relation of form to transpiration.

bly water-holding, as is the mucilage, but this is proven in neither case. To the mucilage, Stahl[24] assigns a function of protection against animals, which its abundance in some non-xerophilous forms seem to sustain. The "Nebenzellen" of the stomata are certainly a xerophilous character, but in what way are they? Probably nowhere else in nature, though it is a xerophilous character, are the rings and spirals better developed in tracheids than here—they are particularly superb in Leuchtenbergia, where as elsewhere they often form gland-like masses along or at the ends of fibro-vascular bundles. What is the use of the spirals in this water-holding family? Can it be that the spiral in a tracheid is associated with the *holding* of water, and that it acts by presenting a larger surface and hence stronger capillary attraction for the water? And are the gland-like tracheid masses really water storers, and if so why are they better than the ordinary pith or cortex cells? The entire internal anatomy of Leuchtenbergia is most beautiful and interesting and the study of its development will prove of great interest. Pits between water cells are particularly fine and show thickened plates at the contact-walls. The hairs show many fine markings and are recommended to those interested in the structure of cell-walls. A micro-chemical study of the tissues is needed, for I have frequently found that the reactions to reagents are not such as our suppositions as to the nature of the walls lead us to expect. The crystals are excessively abundant, doubtless in part because of the very slow growth of desert Cactaceæ and the lack of falling parts, leaves and bark. In certain cases, as in *O. arborescens*, use seems to be made of them for they are deposited in a close single layer, apparently as a sort of armor, just under the epidermis, and perhaps hinder the ravages of snails, or other small animals. But do snails occur on the desert and try to eat the Cactaceæ? This is but one of many examples of what seem to be the converting of a disadvantage to use; probably many of the special secretions, substances once purely excretions but converted to protective purposes, are of this origin.

The Cactaceæ show great "vitality," not only in withstanding bad treatment, but in rooting freely from almost any part, as from the leaves in Peireskia, the tubercles in Mamillaria, etc. Perhaps the possibility of free grafting is another phase

[24] Pflanzen und Schnecken, Jena. 1889.

of it. In what does "vitality" of this sort consist? Is it a more hardy composition of the protoplasm of that plant, or is it in the fact that nearly all cells are alive, i. e., non-skeletal, or a result of the abundant water and food supply in every cell?

The bundle systems are built upon a very uniform system; in the several genera examined they form modifications of that which occurs in Opuntia, which in turn is easily derivable from that of Peireskia. This should be examined for the remaining genera. The bundle systems seem to follow closely external form and morphological changes, a fact which comes out with particular beauty in Mamillaria, where the grooved and ungrooved forms have bundle systems answering exactly to the morphological difference between them. Further study of this relation between internal anatomy and external changes is needed before generalization is possible, but the point is as a principle one of great interest and importance. A careful study of the sieve elements is needed. Many thick forms of Cereus, Melocactus and Mamillaria show a pith-system of interlacing bundles, the development of which is still unknown. In Anhalonium, and confined to it, is found a remarkable bundle-cylinder system. It resembles somewhat, though in more extreme degree, that figured for the separate cylinders of Bauhinia.[25] In cross-section the bundles radiate fan-like in clusters, and then curve about plume-like, so that they often come to face inward towards the center of the stem. Its development is unknown. The entire minute anatomy of this genus, like that of Leuchtenbergia, is of great interest. The composition of the excessively hard cuticle in the rough-tubercled forms, such as *A. fissuratum*, is not known. A latex-system is found in many Mamillariæ (in which the mucilage is generally absent), but its meaning is as little understood here as elsewhere.

The constancy of the behavior of the axillary vegetative points in the same "genus," and the differences in its behavior in different "genera" have suggested that it may be used to indicate true relationships, and I have given in Flora (l. c.) a scheme showing such relationship. This point needs much more full investigation. For systematic purposes, this family needs above all others exact study in the field, for variation is rife in it. The affinities of the family as a whole are not

[25] See Engler & Prantl, Pflanzenfamilien. Leguminosæ, p. 81.

known, different students having placed them in very different positions. If a form is found which will give the transition to some known family, it will probably be a Peireskia-like species growing in the forests of north-western Brazil. All evidence goes to prove the newness of the family, such as their great variability, their lack of sharp divisions between the species and the genera, the large size of some of the latter, the constancy in the structure of the flowers, great similarity in the seedlings, similar characteristics of the axillary vegetative points (differences being derivable by slight modifications in degree), practical confinement in range to a single continent though a very large family, perhaps also their very "vitality," already referred to, including possibility of free grafting and hybridizing.

The study of the development of the flower may give a clue to affinities. Their geographical distribution is imperfectly known. It is worth observing how closely this follows the line of newer mountain chains on the American continent—extending along the Andes and in Brazil to Venezuela through the West Indies to Mexico and northward into the United States.[26]

So much for some of the special questions which, by those who can study the plants in the field or who can command the proper material, should be solvable. In addition to these, certain unusually marked characteristics of the Cactaceæ, in particular their variability, the perfection of their adaptations, and their segregation into many species under a simple environment, make it seem that they are particularly fitted to contribute to the solution of more general problems. As to all of these points, variation, historical development of adaptations, and causes of segregation into species, the old questions remain yet to be answered. Is there or is there not an innate tendency in living matter to variation, or is variation in some unexplained way induced by the surroundings? In the former case, is variation a function of living matter, co-originating with it, or has it been acquired by selection or otherwise, since it gives such good results? In either case, does variation tend of itself to follow certain lines, or is it "fortuitous?" In the former case, are the lines of themselves adaptive or are they adaptive in different directions, natural selection cutting off the unfit and leaving

[26] See the map in Neumayer, Erdgeschichte, **2**: 655.

the fit? I doubt whether we have as yet any certain knowledge upon any of these points. Inseparably bound up with these questions is that as to the direct effect of the external world. Light makes some shoots grow flat: how much of form and size conditions are thus directly imposed, and hence not due to natural selection? How much to internal constitution or mechanical growth conditions? How much to selective action of the environment? The greatest problem of the present time in the dynamics of evolution, is the delimitation of the effects of these three sets of influences: (1) internal constitution, which includes (*a*) properties or functions of protoplasm, (*b*) hereditary characteristics of the particular organism, (*c*) mechanical, physical or chemical conditions of growth; (2) the direct effect of external, mechanical, physical or chemical influences upon the plastic organism either (*a*) directly, or (*b*) through the intermediation of irritability; (3) the preservation of adaptive variations, and the elimination of the unadaptive by the operation of natural selection. A few years ago an overwhelming preponderance was ascribed to the third, but evidence is accumulating to show that the first and second play a part equally, perhaps more, important. I doubt if any family of plants can equal the Cactaceæ, when properly studied, in their bearing upon these matters.

Aside, however, from this, the family is one which the extreme natural selectionist will find it difficult to deal with. On the deserts the conditions of life are comparatively speaking, very uniform. Heat and light, the gases of the air, the minerals of the soil are more than ample for all, and all share practically alike as to rain. Enemies are not numerous, not highly differentiated, and not of the kind with which they come into competition for survival. The plants grow well apart, and the struggle for existence lacks the complexity of forest and jungle and is reduced simply to a struggle with hard but uniform inorganic nature, the scarcity of water being the greatly preponderating element. Such conditions as these should, upon the natural selection hypothesis, produce a monotonous, little differentiated vegetation, for without keen competition between similar or closely related forms, slight favorable differences have no chance of survival over slight unfavorable ones, and hence differentiation along advantageous lines alone could not occur. Now what are the facts? Despite uniform, non-competitive conditions, this family has

produced a thousand species, with some genera including over two hundred species; and in addition has developed hundreds of forms of spines, hundreds of modifications of tubercles and ribs, and hundreds of variations upon other points of its structure. Clearly we must allow for differentiations which are without reference to use. He who believes that differentiation depends solely upon the preservation of favorable over unfavorable variations can find in this family less support for his view than can he who sees in nature the known tendency to variation led along certain lines by little known though omnipresent principles of inertia and segregation, these lines cut off by natural selection when they are opposed to adaptation (*i. e.*, unfit), but allowed when competition is absent to persist whenever not opposed to adaptation (*i. e.*, not unfit, or indifferent) as well as when positively adaptive; until finally when competition comes into play the positively adaptive lines triumph over the indifferently adaptive and natural selection has won the day. I believe the Cactaceæ are in the condition in which there is little competition, and that there are present many indifferently adaptive as well as positively adaptive features of structure, and that the former sometimes are not much behind the latter in degree of differentiation.

Smith College, Northampton, Mass.

Noteworthy anatomical and physiological researches.

Some recent cell literature.

The literature of the various problems touched by studies on the cell increases so rapidly and leads so often to modifications in our knowledge and our theories of cell-phenomena, that the best hand-book very quickly becomes antiquated, perhaps more quickly at present in this field of research than in any other. It is now little more than two years since the appearance of Hertwig's admirable summary of our cytological knowledge, "Die Zelle und die Gewebe," but already certain disputed points there discussed have been further elucidated, and certain views there defended have gained or lost in probability. The request of the editors of the GAZETTE for a brief account of recent literature in its effects on our knowledge of the nucleus and centrospheres seems therefore justifiable. In this discussion we may best take Hertwig's book as a starting point; for, although it treats the cell from the stand-point of the animal histologist, it shows the thorough acquaintance of its author with the botanical literature and his willingness to use it wherever it can throw light on the problems discussed. The present account will, naturally, deal chiefly with the literature of the plant-cell, while referring also to certain important zoological papers.

The question of the nature of the nucleoli and of their fate during karyokinesis is still an open one. While Strasburger and others believe that the substance of these bodies becomes dissolved in the so-called nuclear sap, it is pretty generally held by zoologists to be taken up by the chromosomes. The position taken by Moll (12) may be regarded as an extreme form of this view. He finds in the resting nucleus of *Spirogyra* a very large nucleolus which gradually disappears as the chromatin thread becomes more prominent during the spirem stages. And he believes that he has observed the termination of one end of this thread in the nucleolus, which thus directly furnishes the material for the formation of the chromosomes. Only further studies can definitely decide this important question which bears so directly on the nature of the nucleoli. Zimmerman (20) has observed, like others be-

fore him, that masses of nucleolar substance may sometimes be seen in the cytoplasm during karyokinesis. But this author attempts to show that the nucleoli are characteristically thrown out of the mother-nucleus into the cytoplasm during division, to be reabsorbed into the daughter-nuclei. The present reviewer (9) has attempted to show that this extrusion of nucleolar substance is not constant, nor even common, in any plant studied by him; and Guignard has found (7) in *Psilotum triquetrum* that the frequence of the phenomenon depends, in the sporogenous tissue, upon the stage of its development. The writer can see nothing in the behavior of nucleoli to justify Zimmerman's view of them as organs of the cell. Their indefiniteness in form, size, number, and position in the nucleus, and their total disappearance in most cases during karyokinesis, all point to the conclusion that they are masses of substance subject to the activity of the nucleus and perhaps furnishing plastic material for certain cell-processes, to whatever parts of the cell it may be distributed while unrecognizable as nucleolar masses. And the fact that such recognizable masses sometimes occur in the cytoplasm affords no evidence that the whole of this substance passes normally into the cytoplasm when it disappears during karyokinesis. It is perhaps quite as probable that these masses represent a surplus which is not or cannot be disposed of in the usual way.

The observation of nucleolar masses in the cytoplasm in *Psilotum triquetrum* led Karsten (10) to believe that they are the centrospheres, and that therefore, at least in this plant, the latter bodies are of nucleolar origin. The writer (9) has shown that this was due to his having quite overlooked the true centrospheres, a conclusion since entirely confirmed by Guignard (7).

Since their first discovery in plant-cells by Guignard, the centrospheres have been recognized with more or less certainty by various investigators, so that their occurrence in most of the great groups of plants seems now assured. As has been intimated, the evidence is not equally satisfactory in all cases that the structures regarded as centrospheres by the various writers have really been such. But, as it is practically impossible to determine justly the merits of each case, it may suffice to give a systematic list of those plants in which they are claimed to have been seen, with the name of the observer in each case.

ALGÆ: *Surirella calcarata*, Bütschli, (2); Lauterborn, (11).
Pinnularia nobilis Bütschli, (3).
Spirogyra sp., de Wildeman, (18).
Chara fœtida, Schottländer, (14).
Sphacelaria scoparia, Strasburger, (15); Humphrey, (9).
FUNGI: *Agaricus galericulatus*, Wager, (17).
BRYOPHYTA: *Marchantia polymorpha*, Schottländer, (14).
Pellia epiphylla, Farmer and Reeves, (5).
PTERIDOPHYTA: *Gymnogramme* sp., Schottländer, (14.)
Asplenium sp., Guignard, 1891.
Polypodium sp., Guignard, 1891.
Osmunda regalis, Humphrey, (9).
Equisetum limosum, de Wildeman, (18).
Psilotum triquetrum, Humphrey, (9); Guignard, (7).
Isoetes sp., Guignard, 1891.
GYMNOSPERMAE: *Ceratozamia longifolia*, Humphrey, (9).
ANGIOSPERMAE: *Liliaceæ* (*Lilium*, *Fritillaria*, *Allium*), Guignard, 1891; Schaffner, (13).
Amaryllidaceæ, *Orchidaceæ*, etc. Guignard, 1891.
Tradescantia sp., Guignard, 1891.
Vicia Faba, Schaffner (13).

The fact that they have been seen chiefly in the reproductive cells is due plainly to the greater size and better development of most important structures in such cells. But there is no reason to doubt their occurrence in purely vegetative cells also. Their minute size and the difficulty with which they take up stains makes their recognition in most plants dependent on very favorable conditions for observation. But in some algæ, including some diatoms, according to Bütschli, they are much more easily recognizable, even in the living cell.

In his cell-book Hertwig inclines to the view that these bodies will be found to be of nuclear, rather than of cytoplasmic origin. But the results of the past two years do not, on the whole, favor this opinion. Certain zoologists, notably Brauer (1), believe they have observed them within the nucleus before division, but botanical workers on this point, with the exception of Karsten, agree in finding them in the cytoplasm during the resting stage, in agreement with the original observations of Guignard. Reference may be had to papers by Strasburger (15), Humphrey (9), Guignard (7),

and Schaffner (13). Karsten's theory (10) of the derivation of the centrospheres from the nucleoli has been shared by Julin and other zoologists; but the source of his error has already been pointed out, and the observations of most students of animal cells are equally opposed to this view.

As early as 1888, Boveri gave the name *archoplasm* to the centrosomes with the surrounding cytoplasm, and this term has been more or less loosely used by subsequent writers. Strasburger has more recently (15) proposed to distinguish that part of the cytoplasm which appears to play an active part in karyokinesis, surrounding and including the centrosomes, as *kinoplasm*, from the merely nutrient portion, or *trophoplasm*. And this distinction is a very useful one. In their morphological application, the terms archoplasm and kinoplasm appear to be synonymous. The number of centrosomes present in the kinoplasm of a cell just before division appears to be typically two. In animals and in some algæ the number during the resting stage is but one, and this divides as a preliminary to nuclear division. In the higher plants this division occurs before the resting period, and indeed in the earliest stages of the formation of the daughter nucleus which the kinoplasm accompanies. Heidenhain (8) finds in some animal cells as many as a hundred granules in a group, which he regards as equivalent to a single center. But it seems fair to ask if these may not represent pathological conditions or artificial products. At all events, no such condition has been recognized in plants.

Normal karyokinesis appears to be introduced by the passage to each pole of the nucleus of a part of the kinoplasm with a centrosome, and by the formation, apparently from these starting points, of a spindle-shaped frame-work of delicate fibres. The question as to the source from which the material of these fibres is derived has long been a matter of dispute. Most zoological writers have believed it to be formed chiefly within the nucleus, while most botanists maintain for it an extra-nuclear origin. Flemming now concedes that the ends of the spindle originate outside of the nucleus, while Hermann and the latest writer on karyokinesis in animals, Drüner (4), fully agree with Strasburger in deriving it from the kinoplasm.

The disagreement among zoologists as to whether the spindle

fibres are continuous from pole to pole was due to insufficient knowledge of the facts. The difficulty has been cleared up by the pretty general acceptance of the view that there are formed in some cells, such as the spermatocytes of the salamander, continuous spindle-fibres reaching from pole to pole, and, outside of these, groups of peripheral fibres which reach, at farthest, only to the equator of the spindle; while in other cells, including the egg of *Ascaris megalocephala*, only these peripheral fibres, and none of the central spindle, appear to be formed. Hermann and Drüner derive the central spindle, where it has been observed, from the substance connecting the centrosomes. It appears at first very small and grows as the centrosomes separate. A somewhat similar phenomenon is described by Lauterborn (11) as giving rise to a spindle-like structure in one of the diatoms. This observation needs confirmation, but points to processes of much interest. Strasburger (16) denies the existence of peripheral fibres in the higher plants and finds the threads of the spindle always continuous. Therefore, until our knowledge of facts is much more complete, it is useless to discuss the homologies and significance of the structures above mentioned.

It is, perhaps, in their ideas of the mechanics of the karyokinetic process that vegetable and animal cytologists remain still most widely apart. Most zoologists regard the arrangement of the chromosomes into an equatorial plate and the migration of the daughter-chromosomes to the poles of the spindle as the direct result of the active growth and subsequent retraction of the peripheral fibres. These are believed to grow outward from the centrosomes, attaching themselves to the chromosomes and pushing these before them until they reach the equator, where fibres from opposite poles become attached to the respective halves of each chromosome. Now begins the contraction of the fibres, which results in the separation of the daughter-chromosomes and in their being drawn finally to the poles, on the complete retraction of the peripheral fibres. Drüner (4) also attributes the migration of the centrosomes to the poles of the nucleus to the push of the fibres seen radiating from them at this time, against cell-wall and nucleus, their paths being determined by the resultants of all the pushes to which they are exposed. Many zoologists, with this writer, regard the centrosomes as mere points of attachment for the kinoplasmic threads.

On the other hand, as has been said, Strasburger (16) denies the existence of peripheral fibres in the best-studied plants. Maintaining justly that the splitting of the chromosomes is an active, vital phenomenon, he holds that the movement of the daughter chromosomes to the poles is equally so. He considers the spindle fibres to be the guiding paths along which the chromosomes move, since he and Guignard have found a close correspondence in number between these fibres and the chromosomes. And he believes their motion to take place in response to some sort of attraction exerted by the centrosomes. Yet, since all radiations from the centrosomes are so faintly visible in plant-cells treated by the best known methods, Flemming's suggestion (6) is worthy of consideration, when he hints that an improved technique may bring out the peripheral fibres in these cells, also.

Of the details of karyokinesis in most of the *Thallophyta* we know very little, and most of the accounts we possess contain details so at variance with what we know of other groups, that they must be regarded as requiring confirmation. This seems especially true of the accounts of the centrosomes in these plants which have been published.

Concerning the process of cell-fusion, which constitutes the essential feature of fertilization, there have been no very recent advances on the vegetable side; but it should be noted that recent studies of some American zoologists (19) tend strongly to discredit the supposed fusion in pairs or "quadrille" of male with female centrosomes. The centrosomes of the fertilized egg are said to be furnished sometimes by one, and sometimes by the other sexual element. If this be true for animals, a similar condition may be expected among plants also; but, until Guignard's observations of the quadrille in *Lilium Martagon* are proved erroneous, there is no ground for doubting their accuracy.

Since the present status of our knowledge of the facts concerning the reduction of the number of the chromosomes in the nuclei of the gametophyte, and of their significance so far as plants are concerned, has lately been sketched in this journal (**20:** 23), in an abstract of Strasburger's last paper, it will not be profitable to discuss that most interesting cytological phenomenon here.—J. E. HUMPHREY.

PAPERS REFERRED TO.

1. Brauer, A., Zur Kenntniss der Spermatogenese von Ascaris megalocephala. Arch. f. micr. Anat. **42**: 197. 1893.
2. Buetschli, O., Ueber die sog. Centralkörper der Zelle und ihre Bedeutung. Verhandl. des naturh.-med. Vereins zu Heidelberg **4**: 535. 1891.
3. Buetschli, O., Ueber die Bewegung der Diatomeen. Loc. cit. **4**: 580. 1892.
4. Druener, L., Studien über Mechanismus der Zelltheilung. Jena. Zeitsch. für Naturwiss. **29**: 271. 1894.
5. Farmer, J. B. and Reeves, J., On the occurrence of centrospheres in Pellia epiphylla, Nees. Annals of Botany **8**: 219. 1894.
6. Flemming, W., Zelle, in Merkel und Bonnet, Anatomische Hefte **3**: 113. 1894.
7. Guignard, L., Sur l'origine des sphères directrices. Journ. de Botanique **8**: 241. 1894.
8. Heidenhain, M., Neue Untersuchungen über die Centralkörper und ihre Beziehungen zum Kern- und Zellenprotoplasma. Arch. für micr. Anat. **43**: 423. 1894.
9. Humphrey, J. E., Nucleolen und Centrosomen. Ber. d. deutschen bot. Gesell. **12**: 108. 1894.
10. Karsten, G., Ueber Beziehungen der Nucleolen zu den Centrosomen bei Psilotum triquetrum. Ber. d. deutschen bot. Gesellsch. **11**: 555. 1893.
11. Lauterborn, R., Ueber Bau und Kerntheilung der Diatomeen. Verhandl. des naturhist.-med. Vereins zu Heidelberg **5**: 112. 1893.
12. Moll, J. W., Observations on karyokinesis in Spirogyra. Verhand. d. Kon. Akad. d. Wetensch. te Amsterdam **30**: —. 1893. [No. 9.]
13. Schaffner, J. H., The nature and distribution of attraction-spheres and centrosomes in vegetable cells. Bot. Gazette **19**: 445. 1894.
14. Schottlaender, P., Beiträge zur Kenntniss des Zellkerns und der Sexualzellen bei Kryptogamen. Beitr. zur Biol. der Pflanzen **6**: 267. 1892.
15. Strasburger, E., Schwärmsporen, Gameten, pflanzliche Spermatozoiden, und das Wesen der Befruchtung. Histol. Beiträge **4**: 47. 1892.
16. Strasburger, E., Zu dem jetzigen Stande der Kern- und Zelltheilungsfragen. Anat. Anzeiger **8**: 177. 1893.
17. Wager, H., On the presence of centrospheres in Fungi. Annals of Botany **8**: 321. 1894.
18. De Wildeman, E., Sur les sphères attractives dans quelques cellules végétales. Bull. Acad. roy. de Belgique **21**: 594. 1891.
19. Wilson, E. B., and Matthews, A. P., Maturation, fertilization, and polarity in the echinoderm egg. Journ. Morph. **10**: 319. 1895. See also papers in the same number by Wheeler and Mead.
20. Zimmermann, A., Ueber das Verhalten der Nucleolen während der Karyokinese. Beitr. zur Morph. und Phys. der Pflanzenzelle **2**: 1. 1893.

BRIEFER ARTICLES.

Vitality of Marsilia quadrifolia.—A most remarkable instance of the retention of vitality in the spores of this plant has recently come to my notice. In the summer of 1892 I gathered fertile specimens at Fresh Pond, near Cambridge, Mass. The rhizomes and their attached sporocarps were at once put into commercial alcohol (95%) and have been kept therein continuously to the present time. Spores from specimens used by a student in morphology (Miss Anna Tarnutzer) were left in water in the dissecting dishes for several days. When about to clean up the dishes Miss Tarnutzer was surprised to find young plants in the water. She called my attention to them and examination showed that they were young sporophytes of Marsilia, with shoots an inch or more long and roots well developed.

It was thought that this might be exceptional, and Miss Tarnutzer was directed to select spores from a freshly opened sporocarp and sow them in water. These also germinated as did many others which were tried, and the class was able to study the prothallium and sexual organs as well as the developing sporophyte.

The sporocarp of this plant is of course very resistent, but one would hardly expect it to be able to exclude alcohol so completely during three years immersion as to leave both microspores and megaspores capable of germination.—CHARLES R. BARNES, *University of Wisconsin.*

Aspidium simulatum DAVENPORT.—Since the publication of this species I have received specimens for examination from a number of sources and found that my suspicion in regard to its having been many times collected for either *Aspidium Thelypteris* or *A. Noveboracense* was well founded.

I give the following additional stations not only as an indication of its range, but as positive evidence that botanists may expect to find it masquerading under one or the other of its congeners' names in their herbaria:

"Sawmill Pond, Anne Arundel co., Maryland, October 1, 1894, in wet thickets and quite plentiful."

Collected by C. E. Waters, Johns Hopkins University, Baltimore, who writes that "the sporangia were still unopened, but so nearly ripe that on taking the fronds from the damp driers the dry air caused the sporangia to open so rapidly that a decided crackling noise could be

heard." He also writes that "with us *A. Thelypteris* ripened this year (1894) in the early part of September, and *A. Noveboracense* in July or August," confirming my own observations on the relative differences in the development and ripening of the three ferns.

From Prof. Trelease of the Missouri Botanical Garden I have received specimens collected on Poplar Bluff, S. E. Missouri, August 15, 1875, by George W. Letterman, and at Sapulpa, Indian Territory Sept. 24, 1894, by B. F. Bush, no. 847, ticket marked "common."

There are a few forked veins in the lowermost pair of pinnæ on Mr. Bush's specimen, and it will be noticed that the date for Mr. Letterman's is the earliest yet recorded.

The species has also been collected by Mr. Merritt L. Fernald, of the Cambridge herbarium, in Georgetown, Maine, in a different locality from that recorded by myself.

Erratum.—By a careless inadvertence, for which I alone am responsible, in my account of the habitat of this species (Bot. Gaz. 19: 496. 1894) Seabrook is made to appear in Essex co., Mass., instead of New Hampshire, where it belongs; Essex co., Mass., should follow Salisbury.—George E. Davenport, *Medford, Mass.*

Dr. Joseph Schrœter. — This eminent mycologist died at his home in Breslau, Dec. 12, 1894. His name and works are well known to American botanists, who regarded him as a leader in the departments of knowledge which he cultivated. The following account of his life is taken in the main from an article in the *Botanisches Centralblatt*, by Dr. H. Kionka of Breslau.

Schrœter was born in Potschkau in Upper Silesia, March 14, 1837, and was therefore only in his fifty-eighth year at time of his death. As a boy he was fond of plants, but being the son of a physician he naturally devoted himself to medicine, upon the completion of his gymnasium studies. He took his doctor's degree in Berlin at the age of twenty-two, and then entered military service. He was soon made an army surgeon, and in 1865 was promoted to the position of staff surgeon in the royal grenadiers stationed at Breslau.

During these years he still found time to pursue his botanical studies. When the Plant-Physiological Institute was established at Breslau in 1866, under the management of Prof. Cohn, Schrœter became the first investigator to enter, and maintained his connection with the institution up to the time of his death. He at first assisted Professors Cohn and Koch with their famous studies upon bacteria, and published a number of his own researches in this line, but was soon diverted to the study of the fungi, especially parasitic forms, which he made his life work. He opened Cohn's classical series of *Beiträge zur Biologie der*

Pflanzen in 1870 with a monograph upon Synchytria. He now contributed also to the botanical section of the *Schlesischen Gesellschaft für vaterlandische Cultur*.

When the Franco-German war broke out in 1870 he followed his regiment to the field, and was in a number of engagements, including the battle of Sedan. His services were recognized both by promotion and decoration. In 1874 he was again stationed at Breslau, and returned to his studies of the fungi with greater zest than ever. In the following year upon the occasion of the half century jubilee of Göppert's doctorate, he undertook the elaboration of the fungi for the cryptogamic flora of Silesia, a work inaugurated by the *Gesellschaft* already mentioned.

This great work could not have been carried out by one better fitted for it, as he had himself first collected most of the species, and had first described many of them. Unfortunately it was not quite finished at his death. The first volume was published in 1889, and of the second and last volume three lieferungen still remained unpublished. The necessary manuscript was ready, however, with the exception of about one signature. The portion to be supplied embraced part of the fungi imperfecti, which must now be prepared by other hands.

Through this work and a number of monographs of separate groups of fungi he has become known at home and abroad as one of the foremost mycologists of the time. He had begun the elaboration of the fungi for the monumental work of Engler and Prantl, *Die natürlichen Pflanzenfamilien*, but had only prepared a few orders. Besides this he had recently begun to issue the *Pilze Schlesiens* in exsiccati, to serve as a basis to his cryptogamic flora of Silesia. Of this only 400 numbers in an edition of about twenty-five copies had been issued at time of his death.

In 1886 Schroeter qualified as a member of the Breslau medical faculty in the department of mycology and bacteriology, and in 1890 became a professor. In 1892 he was entirely relieved from military service.

He was an exceedingly industrious collector, and in the last few years, especially, extended his travels over a wide range of country, covering all of Europe from Italy to the North Cape. Last summer he undertook a scientific expedition to Asia Minor, stopping at Cyprus, and especially remaining in Cilicia and the Taurus mountains. In the unhealthy climate he contracted malaria, which developed into a fever upon his return home. During the autumn there was a recurrence of the fever from time to time, and in one of these attacks, which kept him upon a sick bed for only a few hours, he expired.

Schrœter was much beloved, and greatly appreciated for his high attainments by those who knew him best. To the scientific world his loss is well nigh irreparable.—J. C. A.

Collinsia bicolor.—While studying the genus Collinsia with reference to future revision, certain peculiarities of structure in the flower of *C. bicolor* have come to light which seem to be of sufficient significance to merit some mention in the GAZETTE.

At the point where the upper pair of stamens become free from the corolla, the wings of the filaments turn into the sac of the corolla. After continuing attached to the corolla by one edge for a little way they end in free tips which are somewhat bearded. These tips point out into the sac so that they almost meet over the rudimentary fifth stamen or gland at the base of the sac.

The conclusion arrived at after careful study of the question was that their function is to guard the nectar gland. The utility of such a device can readily be seen. The four stamens are declined toward the lower lip of the corolla and clasped by its middle lobe; so that the insect must enter by this path in order to reach the pollen. But the throat is so large and with such a wide opening that the insect could easily enter and reach the gland without coming in contact with the pollen, were it not for these guards, which effectually bar this road to the nectar.

The same phenomenon has been observed in milder form in *C. franciscana*. Both species are easily distinguished from all others by this peculiarity.—ALICE E. KEENER, *Herbarium Lake Forest University.*

EDITORIAL.

THE TRANSFER of the National Herbarium from the building of the Department of Agriculture to the care of the Smithsonian Institution, and its storage in the National Museum, is a movement that commends itself to every botanist. That this great collection should so long have been exposed to destruction by fire does not reflect much credit upon our Congresses; and as the present arrangement seems to have been easily effected without any congressional action the long time exposure does not reflect much credit upon previous administrations of the Department of Agriculture. The Smithsonian Institution does not furnish more room, for the National Museum is already overcrowded, but it furnishes safety, and is the proper depository of government scientific collections. In the transfer, the collections of the Divisions of Vegetable Pathology and of Forestry are not included, and the Department of Agriculture also wishes to retain the grasses. In our judgment all of these collections should pass under the care of the Smithsonian Institution, for the same reasons obtain for their transfer as for the transter of the other collections. The botanist of the Department of Agriculture retains his position of Curator, so that a transfer does not put any obstacle in the way of use. The collections of the Division of Vegetable Pathology and of Forestry are in charge of other curators, so that it may be well to preserve their autonomy, but the great and in many respects unique collection of grasses should certainly be included in the transfer.

THIS COMMENDABLE movement, however, is but a temporary expedient, for it means storage rather than working room. The Botanical Club, and the other organizations comprising the same body of botanists, through their annual resolutions on this subject, seem to have been effective thus far, and should be encouraged to continue their effort until a suitable building is provided on Smithsonian grounds. Much has already been done in the elimination of congressional clerks and replacing them with botanists. A building and an adequate corps of competent investigators are due such a collection as the National Herbarium. We trust that this matter will be taken up at every meeting of botanists, until the National Herbarium has a proper equipment of room and of men.

CURRENT LITERATURE.

Field, Forest and Garden Botany.[1]

Of all the books which Dr. Gray found time in his busy life to prepare, none has been so widely used in schools as the manual which included the common cultivated plants. Although the first edition appeared in 1868, at the time of his death he was only hoping to find time to revise it. Shortly after his death, provisional arrangements were made by Dr. Watson for its revision, which was begun by Professor Barnes. A change in his plans, and a growing conviction that he could not do the work satisfactorily under the limitations imposed, impelled him to ask after Dr. Watson's death for release from the agreement. At that time a preliminary list of the species to be included had been made, and also the first draft of the manuscript through the Leguminosæ. The corporation of Harvard College then placed the prosecution of the work in the most competent hands of Professor Bailey, to whom therefore belongs the credit for the whole revision.

The book appeared early in the present year. It is really much more than a revision, since it now includes eighty-two genera and 553 species more than the original. This increase is partly due to extension of territory west to the 100th meridian and more largely to the great increase in the number of plants now in common cultivation. In plan, arrangement, and style of description, as well as nomenclature, the book is still Dr. Gray's; the reviser's aim being to bring it down to date. The only noteworthy innovation is the placing of the gymnosperms after the angiosperms, instead of between the dicotyledons and monocotyledons, a change to which Dr. Watson's reluctant consent was obtained.

The most difficult part of the work of revision naturally is to determine what to leave out. Prof. Bailey has been happy in the omissions he has made as well as in the choice of species to be included. In fact throughout the revision his wide knowledge of cultivated and wild plants is apparent.

If any criticism is to be made upon the book it is that Prof. Bailey has not revised it enough. Dr. Gray always considered it the most

[1] GRAY, ASA:—Field, forest, and garden botany, a simple introduction to the common plants of the United States east of the 100th meridian, both wild and cultivated; revised and extended by L. H. Bailey. 8vo. pp. 519. American Book Co. 1895.

crude of his books because it was made in an incredibly short time; it would have been wise therefore for the reviser to give more attention to unifying its descriptions and because of their brevity to make sure that contrasted characters were used in related species as well as in section characters. In both these points the original was conspicuously defective and the revision therein is not materially better, as will be evident to any one by even casual comparison. Considerable space might have been saved also in remarks under each genus by condensing the explanation of the name. It may be objected that these changes would have made the book mechanical and have eliminated the peculiar happy touches characteristic of Dr. Gray. Yet they are just such changes as Dr. Gray would probably have made himself; and in a manual one expects formality.

In typography a marked improvement has been made in indicating indigenous and exotic species and horticultural forms by special type. Though having the same sized "body" as the first edition the type of the new book has a larger and clearer face and makes a fair page. It is quite certain that the revision and extension of this book will insure for it a new lease of life and a still wider use. We wish the Herbarium whose property it is a large income from its sale.

Minor Notices.

THE SECOND EDITION of Spalding's "Introduction to Botany"[1] has recently been issued. It has been improved by the addition of a chapter on fungi, and a glossary and index. There have been some minor changes made here and there, but the arrangement and mode of treatment have not been altered. We can recommend this edition even more heartily than we did the first. It contains too much work for the ordinary high school, but the teacher who can not from it select a suitable course, or who finds it "too advanced" for his class may well question his fitness to teach botany as it ought to be taught in a high school laboratory.

THE "BUSHBERG CATALOGUE" is by no means merely a trade catalogue, but is widely and most favorably known as a comprehensive and reliable manual of grape culture. So important is it, particularly in its descriptive list of varieties that earlier editions were translated into French, Italian, German and several other languages. The fourth

[1] SPALDING, V. M.—Guide to the study of common plants, an introduction to botany. Ed. 2. 12 mo. pp. xxiii + 294. Boston, D. C. Heath & Co. 1895.

edition has now been issued,[1] twenty-five years after the publication of first. Although the third edition, issued eleven years ago, was soon exhausted the publication of this has been delayed until the perfecting of the remedies for grape diseases has given renewed confidence in the success of grape growing. The firm of Bush & Son & Meissner have had the cooperation in preparing this work of various gentlemen. B. T. Galloway, contributed the article on fungous diseases and their treatment; T. V. Munson, whose studies of the grape have extended over fifteen years, furnishes a classification of the grapes, though the article by Dr. Geo. Engelmann in previous editions has been continued; C. V. Riley has revised the article on insects. The descriptive list of varieties occupies over 100 pages, and by its typography shows the rank of each. The pamphlet is profusely illustrated.

THE DRUG DAMIANA is treated in its botanical features by John S. Wright, with illustrations, in *Lilly's Bulletin* No. 25. It is composed of the dried leaves, young shoots, and occasional flowers and pods of *Turnera diffusa aphrodisiaca*, a suffrutescent plant of western Mexico, also reported from Texas. *Aplopappus discoideus* has sometimes been substituted for it. The drug has been known in this country for only about twenty years, but on account of strong tonic character has gained favor rapidly among physicians.

THE LABORATORIES of Natural History of the State University of Iowa have devoted the first part of volume 3 of their *Bulletin* to the narrative of the Bahama expedition sent out by the institution in 1893. The number contains 250 pages and many plates.

FOUR STATION BULLETINS upon weeds are as follows: The Russian thistle in Ohio, with poster supplement, by A. D. Selby (Ohio, no. 55), general account, and a copy of the state weed laws: Five farmers' foes by Moses Craig (Ore., no. 32), brief account of Cnicus arvensis, C. lanceolatus, Sonchus arvensis, Xanthium spinosum and Salsola Kali tragus, with copy of state weed laws; New Mexico weeds, I, by E. O. Wooton (N. M., no. 13), some account of weeds and their treatment, with descriptions of eighteen of the worst kinds, finely illustrated from photographs; Distribution of weed seeds by winter winds, also effect of seed exchange upon the culture of wheat by H. L. Bolley (N. D., no. 17), observations on the number of seeds in snow drifts and the action of winds in carrying free seeds.

[1] BUSH & SON & MEISSNER:—Illustrated descriptive catalogue of American grape vines; a grape growers' manual, 4th ed. 8vo. pp. 198. The authors, Bushberg, Mo. 1895. Fifty cents.

NOTES AND NEWS.

THE BOTANICAL SOCIETY OF ITALY celebrated the centennial of its establishment April 15–23d.

DR. ALFRED KOCH has been appointed a.-o. professor of vegetable physiology in the University of Göttingen.

THE FORTHCOMING supplementary volume of Saccardo's Sylloge Fungorum will be XI, and not IX as stated in the April GAZETTE.

DR. V. HAVARD has published, in *Bull. Torr. Bot. Club* (March), a very interesting paper on the food plants of the North American Indians.

PROF. L. H. BAILEY contributes to the special spring trade edition of the *Florist's Exchange* (7: 387. 30 Mr 1895) an account of the evolution of American horticulture.

GASTON, MARQUIS DE SAPORTA died at Aix, Provence, on January 26, at the age of 72. He was pre-eminent among students of the fossil flora of Tertiary and Mesozoic formations.

PROF. LEON GUIGNARD has received the high honor of election to the French Academy, succeeding the late Duchartre. Botanists will heartily approve this action as a recognition of genuine merit.

MR. E. H. ACTON, who has become known to American botanists chiefly through his book (in conjunction with Mr. Francis Darwin) entitled "Practical Physiology of Plants," died suddenly at Cambridge, England, from heart disease, on February 15th.

A NEW PLANT HOUSE over 170 feet long, and of handsome construction, has been erected at the Central Experiment Station of California. It cost about $13,500. It is located beside the botanic garden of the University, which has now become an important adjunct of the botanical department.

THE "SPRAY CALENDAR," sent out by the horticultural department of the Cornell Experiment Station, both last year and this, giving directions for combating plant diseases, has beeen reprinted by the Missouri Station and variously imitated by others. It is a model in way of concise statement.

THE DEATH OF ISAAC SPRAGUE, which occurred March 15th at his home in Wellesley Hills, Mass., removes a botanical artist whose name will always be closely associated with that of Dr. Asa Gray. There was nothing finer at the time than Sprague's illustrations, and his studies set the pattern for later botanical artists.

THE NEW YORK UNIVERSITY announces summer courses to continue from July 9th to August 17th, consisting of mathematics, physics, chemistry, biology, experimental psychology and pedagogy. The course in "biology" has not the faintest trace of a botanical side to it,

or any indication that the organic world contains any other forms than those of animals. The vegetable world can not be said to be ignored by the professor in charge, but rather undiscovered.

M. Ed. Bureau has announced the publication, under his direction, of a series of French colonial floras, of the same general style as the colonial floras prepared at Kew. The work has been assigned to several botanists, and the material for study is contained in the great herbaria of the Museum. Some of these floras have already appeared.

Prof. F. Lamson-Scribner has just published, from the Department of Agriculture, accounts of "the flat pea" (*Lathyrus sylvestris Wagneri*) and "sachaline" (*Polygonum Sachalinense*), both of them forage plants, concerning which large claims have been made. Accounts are given which should temper enthusiasm, and at the same time inform concerning the possible service of these plants.

Prof. Lester F. Ward, in *Science* (March 29th), has compared the Mesozoic flora of Portugal with that of the United States (Potomac beds), finding a remarkable parallelism. The occasion of the paper is the appearance of Marquis Saporta's "Flore fossile du Portugal." The archetypal angiosperms, "Protangiosperms," are also discussed, which seem to be remarkable illustrations of what were once called "comprehensive types."

American woods prepared and published by R. B. Hough of Lowville, N. Y., has reached the sixth volume. The work consists of thin sections of wood, mounted in book form, and accompanied with explanatory text. Each volume embraces twenty-five species. The first four volumes include most of the woods of New York and the adjoining states, volume five is devoted to Florida woods, and volume six to those of California.

Experiments with cultures of algæ (Conjugatæ), by Bokorny, to determine the effect of the absence of calcium and magnesium on the cell organs, lead him to the conclusion that the absence of Ca occasions a poorly developed chlorophyll apparatus, while the want of both Ca and Mg entails a shrinkage of both nucleus and chlorophyll bodies. A decided diminution in the size of the nucleus seemed also to result from the lack of Mg alone. (Cf. Bot. Centralb. 62: 1. 1895.)

Plant models, showing the course of the fibrovascular bundles in the stem, forms of the embryo, arrangement of the apical cells, mechanical system of leaves and stems, reproductive organs of liverworts, stomata, arrangements of flowers for pollination, and many other structures, are offered for sale by Heinrich Gasser, whose address is Graz III, Leechgasse 22 E, Austria. The models of stomata and flowers have movable parts, to show the natural automatic movements. A price list will be sent on application.

Even the *Index Kewensis* is held up to obloquy *in re* nomenclature! In a paper (from Proc. Cal. Acad. Sci. II. 4: 559. 19 Mr 1895) on two species of Aquilegia Miss Alice Eastwood remarks anent her *A. ecalcarata*, "According to the Index Kewensis, A. ecalcarata is a synonym

of *A. vulgaris* L. As I am not in sympathy with the movement that is producing such chaos in nomenclature and do not care to become a name changer myself, I leave it with the name under which it has been described." How easy!

THE FIRST FASCICLE of *Musci Europaei Exsiccati*, issued by MM. F. Renauld and J. Cardot has been distributed. American bryologists who desire European species for comparison with our own are advised to procure this set of exsiccati. The specimens are ample and well prepared, while the names of the authors are a guarantee of care and accuracy in the determinations. Prof. J. M. Holzinger, Winona, Minn., is the author's agent in this country.

THE *Bull. de l'Herb. Boiss.* for February contains a list, with descriptions of many new species, of the *Graphideæ* of Eckfeldt collected in Louisiana and Florida, by Dr. J. Müller; a continuation of the fungi of equatorial regions (with plate), by Patouillard and Lagerheim, containing numerous new species and two new genera (*Punctularia*, a hymenomycete, and *Xylobotryum*, a pyrenomycete); and descriptions of new oriental caryophylls, by J. Freyn.

ANOTHER SERIAL PUBLICATION! Alas the day! The first volume of the Memoirs from the Department of Botany of Columbia College, now in press, contains *A monograph of the North American species of the genus Polygonum*, by Mr. John K. Small. It is illustrated by life-sized figures of all the species and by figures of the stem anatomy of the several subgenera. There are eighty-six plates in all and about two hundred pages of text. The Memoirs will be issued at irregular intervals—probably at long intervals—and each volume or part will be published at a fixed price.

PARTS 113, 114, 115 and 116 of *Die natürlichen Pflanzenfamilien*, just issued, contain the completion of Guttiferæ by Engler, Dipterocarpaceæ by Brandis and Gilg; Ancistrocladaceæ by Gilg; Elatinaceæ and Frankeniaceæ by Niedenzu; the completion of Borraginaceæ by Gürke; the beginning (55 genera) of Verbenaceæ by Briquet; the completion of Bignoniaceæ by Schumann; Pedaliaceæ and Martyniaceæ by Stapf; Globulariaceæ by Wettstein; and the beginning (122 genera) of Acanthaceæ by Lindau.

DR. F. W. KLATT, in *Ann. k. k. naturhist. Hofmuseum* (9: 355), describes forty new Compositæ from tropical America (Mexico, Central America, and the northwestern South American states) from material in the herbarium at Vienna. As this region is just now receiving large attention from American botanists it is well to note that this fascicle contains new species of the following genera: Eupatorium (10), Brickellia (1), Heterotheca (1), Aster (1), Baccharis (1), Lagascea (1), Baltimora (1), Schizoptera (1), Sclerocarpus (1), Viguiera (1), Verbesina (2), Liabum (2), Culcitium (2), Senecio (10), Gynoxys (1), Werneria (2), Othonna (1), Crepis (1).

BULLETINS 5 and 7 of the North Carolina Geological Survey are devoted to forestry. No. 5 treats of the forests, forest lands, and forest products of eastern North Carolina; and no. 7 of forest fires, their destructive work, causes, and prevention; both by W. W. Ashe,

who is in charge of the forest investigation. The reports are exceedingly well prepared and deal with one of our most important forest areas. Attention is specially called to the continued and unnecessary destruction of the forests of the eastern counties by fires and stock and the importance of remedying the evil before it is too late; and also to the fact that the quality and value of the "naval store" products may be increased some $200,000 per year by the adoption of the French system of gathering the turpentine.

PROF. L. M. UNDERWOOD, in *Bull. Torr. Bot. Club* (March), makes a plea for uniformity in the names of the larger plant groups, illustrating his suggestion by outlining the archegoniates. There has been great variance in usage among the systematists who have dealt with phanerogams, while the cryptogamists and zoologists have been more uniform. The proposition is to conform to the long established zoological usage, and to use as primary divisions the following terms and sequence: sub-kingdom, class, order, family, genus, species. This does away with such terms as "branch," "series," "cohort," which have crept in among phanerogams, and makes an "order" stand for a group of related families. Professor Underwood would recognize four sub-kingdoms: Mycetozoa, Thallophyta, Archegoniata, and Spermatophyta, the first two sub-kingdoms being as yet essentially tentative. Under Archegoniata the author would include three classes, Bryophyta, Pteridophyta and Gymnospermæ. Under Bryophyta he would recognize seven orders, abandoning the long-used sub-class names, Hepaticæ and Musci, as meaningless. The general suggestion certainly has very much in its favor.

VEGETABLE PATHOLOGY is treated, in some of its phases, largely or exclusively in the following bulletins from the experiment stations: Potato scab by H. J. Wheeler, J. D. Towar and G. M. Tucker (R. I., no. 30) gives the results in the development of scab when the soil conditions are varied; Potato blight and scab by F. Wm. Rane (W. Va., no. 38); Potato scab and its prevention, also Bacteriosis of rutabaga by L. H. Pammel (Iowa, no. 27) giving results of experiments and microscopic study; Field experiments with fungicides on turnips, cabbage, tomatoes, potatoes and beans by B. D. Halsted and J. A. Kelsey (N. J., no. 108); Treatment of smut in wheat and potato scab by H. L. Bolley (N. D., no. 19), a condensed statement with directions for field use; Grain smuts and potato scab by Aven Nelson (Wy., no. 21), outline of the subjects for information of the cultivator; Spraying orchards and potato fields by L. R. Jones (Vt., no. 44), embodies experiments of 1894; Some fungous diseases of beets by B. D. Halsted (N. J., no. 107), describes three common and three rare diseases; Spraying pear and apple orchards by S. A. Beach (N. Y., no. 84) gives results of experiments; Black knot by E. G. Lodeman (Cornell, no. 81) includes observations on mode of entrance of the spores, results of spraying and a bibliography; The quince in western New York, also Recent apple failures in western New York by L. H. Bailey (Cornell, nos. 80 and 84), both partly devoted to diseases, the latter especially treating of apple scab (Fusicladium) with good illustrations, including a colored plate.

FOR SALE CHEAP

Botanical Gazette, Volumes XII, XIII, XIV, XV, XVI, unbound, $9. **Nuovo Giornale Botanico Italianzo,** Vols. XIX to XXIV, inclusive, unbound, Nos. 1 and 2 of Vol. XXV; and **Bullitino della Societa Botanica Italiana,** complete for 1892 and four numbers for 1893. Price, $10.

Address, **C. S. PLUMB,**
LA FAYETTE, IND.

FLORA OF WASHINGTON

The undersigned offers for sale sets of Washington plants. Fascicles X and XI are now ready. Price 8 cents per specimen.

W. N. SUKSDORF,
WHITE SALMON,
Klickitat Co. WASHINGTON, U. S. A.

...Oels' Experimental Plant Physiology...

Translated and Edited by D. T. MacDougal.

A concise laboratory manual, containing chapters on absorption of nutriment, respiration, photosynthesis, geotropism, heliotropism, heat, growth, and movement. 122 Experiments. 77 Illustrations. Used in a large number of schools, colleges, and universities. Half flexible cloth binding; by mail, postpaid, $1.10.

MORRIS & WILSON, Publishers, Minneapolis, Minn.

VINES' TEXT-BOOK OF BOTANY

Part II is just out. We sell both parts. Send to us for all new botanical works, American and foreign. We make a special effort to supply any paper listed in the monthly Bibliography of American Botany.

EVERYTHING USEFUL TO BOTANISTS

Cambridge Botanical Supply Company

CAMBRIDGE, MASS.

Memoirs from the Department of Botany of Columbia College—Volume I.

A Monograph of the North American Species of the Genus Polygonum. Quarto, pp. 178. 85 plates. Price $6.00.

PROF. N. L. BRITTON,
Columbia College, New York City.

SPECIALLY PREPARED

Herbarium Paper for Botanists

This paper is offered at the moderate price of $5.50 per ream. We also furnish—

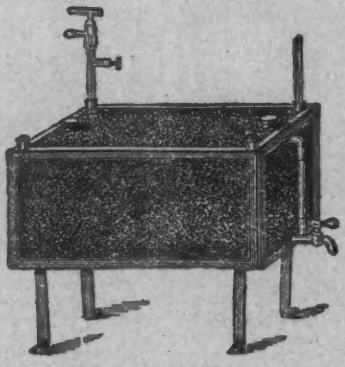
No. 1 Genus Cover,		16½	x 24 inches, at	$4.00	per 100
2	"	"	"	2.50	"
3	"	"	"	1.50	"
Dryers,		12	x 18 "	2.00	"
Species sheets,		16½	x 23½ "	.50	"

Orders will receive prompt attention. Write for samples.

E. MORRISON PAPER CO.,
1009 Penna. Avenue, N. W., Washington, D. C.

Henry Heil Chemical Co.,

ST. LOUIS, MO



CHEMICALS, GLASSWARE

AND OTHER APPARATUS FOR CHEMICAL, BOTANICAL, AND BACTERIOLOGICAL LABORATORIES.

IMPORTERS OF

SPECIAL APPARATUS FOR Vegetable Physiology.

GIVE US A TRIAL. YOU WILL FIND US PROMPT AND CHEAP.

Before Ordering Elsewhere, Get Our Quotations.

Large Illustrated Catalogue on Application.

WE HAVE MADE

MARKED IMPROVEMENTS

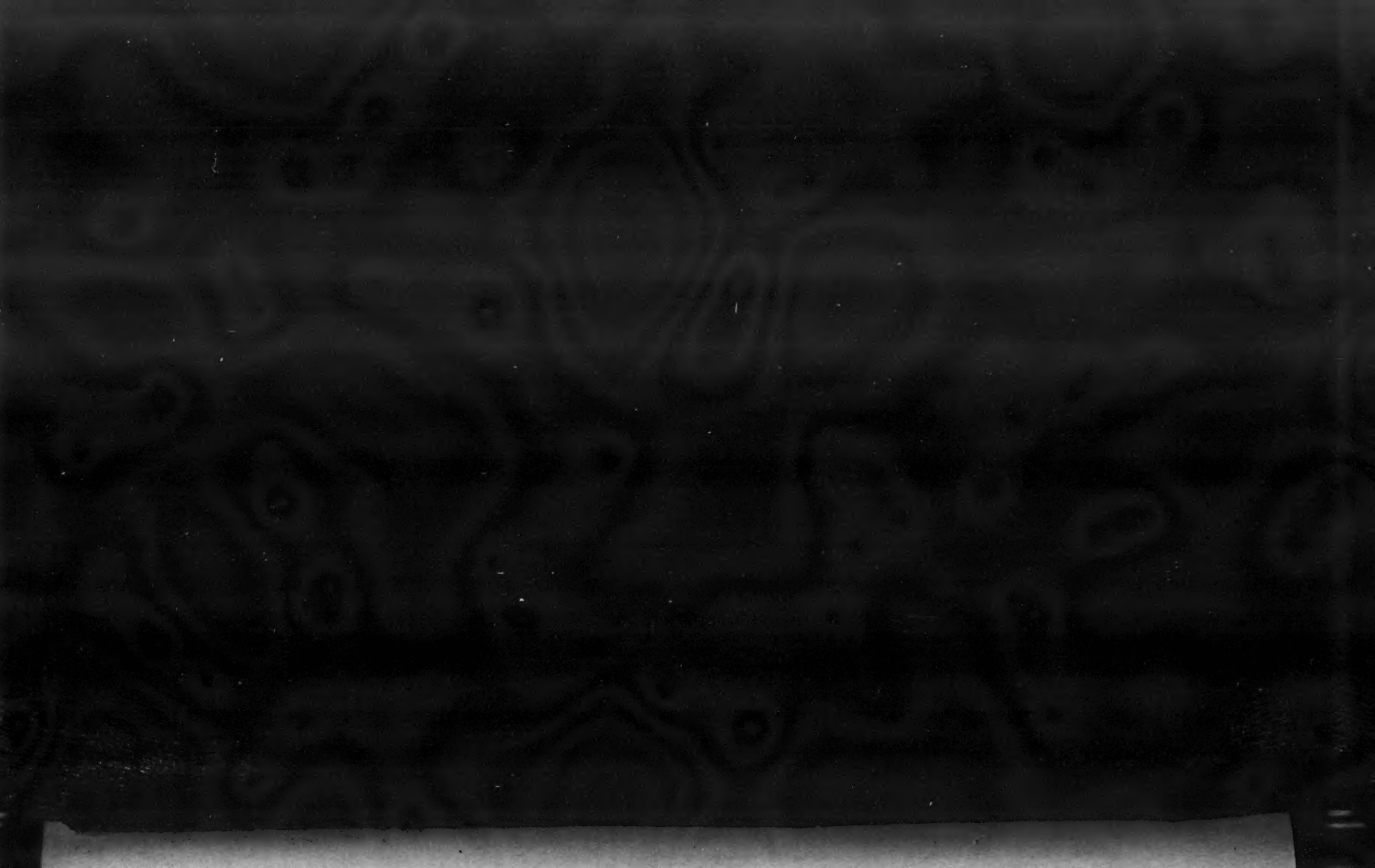
in the construction and workmanship of our Dissecting and Compound

MICROSCOPES

within the past year. This we accomplish by ingenious and delicate special machines and by a systematic division of labor. This also enables us to offer them at

REDUCED PRICES

to institutions, lower than European prices on the duty-free basis.

BAUSCH & LOMB OPTICAL CO.

ROCHESTER, N. Y. NEW YORK CITY.